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Somes Sound Spring 1986 Study

Part 1

Text

Prepared for

The Somes Sound Association

and

The Town Of Mt. Desert

September 28, 1986

By Carl B. Ketchum, Ph.D.
Physical Oceanographer
College of The Atlantic

and

Donald Cass, Ph.D.
Chemist
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1 Introduction

The study described in this report was initiated following the December 17, 1985 hearing in the town of Mt Desert on a proposed Atlantic salmon hatchery for Somes Sound. Not only had the hearing demonstrated how little was actually known about the waters of Somes Sound, but many residents of the sound had also noted significant decreases in local fish in the sound and, over the years, an increase in algae growth on mooring lines and other structures in the sound. The goals of this report were to 1) determine spring stream flow and nutrient transport flow into the sound 2) measure the spring temperature and salinity[1] structure of the sound and estimate the flushing rate during spring conditions and 3) to make a preliminary survey of the surface nutrient distribution of the sound. The overall study has been funded by the Somes Sound Association and the Town of Mt. Desert. The National Park Service provided the boat Miss Anne and the captain Mr. Carroll Schell for the two cruises.

During two full day cruises on Somes Sound on April 15 and April 19, 1986, vertical profiles of temperature and salinity as well as surface nutrient samples were collected at selected stations within the sound. At the same time stream flow in selected streams around the sound was estimated from field measurements. The nutrient inflow rates for several streams into the sound were determined in a series of field studies conducted from June 2 to 10, 1986.

The discussion section beginning on page 22 summarizes and explains the main results of this study. The intervening pages examine previous studies and report on the methods and results of this study. Some readers may prefer to move to the discussion section before reading the details contained below.

2 Previous work

The most comprehensive study of Somes Sound Waters is the work of Folger et al (1972) which reports on a study of the sound in

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1. Salinity is essentially a measure of the total mass, in grams, of dissolved salts in one kilogram of sea water. Since 1978, salinity has been defined in terms of a ratio of the electrical conductivity of a sample of sea water to that of a standard and it is reported without units, i.e 35.00. Older literature generally reports salinity as parts per thousand

August, 1969. That study explored the temperature, salinity, oxygen and suspended sediment content of the waters, determined the sediment characteristics at 83 different stations in the sound and measured the biological oxygen demand at selected stations. In addition, an acoustic sea bed drifter was followed for eight tidal cycles to obtain initial information on the tidal circulation near the mouth of the sound.

Temperature and salinity data in August, 1969 indicate that the summer temperatures of the deep waters are between 12 and 13°C with the temperatures increasing over the upper 10 to 15 meters to 17°C at the surface during high water. The low water surface values are slightly cooler (14 to 15°C). Summer salinities are uniformly between 30 to 31 except near the head (Somes Harbor) where the influence of fresh water inflow from streams drops the salinity to 28 at low water. The dissolved oxygen content is on the order of 6 ml/liter and does not drop below 4 ml/liter - a condition indicating a healthy supply of oxygen.

The upper regions of the sound are primarily covered with fine clay; sediment texture becomes coarser toward the mouth changing from clay to silt, sand and finally gravel. The coarser sediment distribution toward the mouth is most likely due to a more active bottom water flow in this region. The concentration of organic carbon increases from 1 percent to 4 percent toward the head of the sound with slightly higher values on the western side while the concentration of calcium carbonate increases from a low of 0.5 percent near the head to a high of 20 percent near Valley Cove. The conclusion reached by Folger et al is that the source of most of the organic carbon is near the head of the sound while the source of the calcium carbonate (shell fragments) is nearer the mouth. The slight increase in calcium carbonate along the western edge of the sound coupled with the increased concentration of organic carbon along the eastern edge in the upper sound indicates a residual counterclockwise circulation within the deep waters of the sound, with a stronger inflow occurring along the Northeast Harbor side of the sound and a slightly stronger outflow occurring near Hall Quarry. The sediment survey also indicated the presence of hydrogen-sulfide near the upper region of the sound. Large concentrations of hydrogen-sulfide often suggest the presence of anoxic (low or no oxygen) conditions.

Measurements of biological oxygen demand provide an estimate of the bacterial load in the water. Results are obtained by incubating sea water in a dark environment for a period of 48 hours and determining the amount of oxygen used. Higher oxygen usage indicates a heavier load of bacteria. Folger's measurements in Somes Sound show surface values ranging from 0.65 near the mouth to 1.15 ml/liter near the head with deep water values being near 0.6 ml/liter. These values are intermediate between the clear coastal waters of Hawaii (0.2 ml/liter) and the waters of the Chesapeake Bay (3 - 4.5 ml/liter).

Other research related to Somes Sound will be introduced as needed in the body of this report.

3 Data cruises

We conducted two survey cruises on Somes Sound on April 15, 1986 (Cruise I) and April 19, 1986 (Cruise II). Cruise I sampled conditions at 20 different stations within the sound (designed to provide three cross-sound sections and one along-the-sound section.) Station locations for Cruise I are indicated in Figure 1. The along-the-sound section (roughly North-South) was sampled during high tide. Cruise II sampled conditions at various depths at 14 stations and collected surface samples at 10 other stations. This cruise was designed to repeat the along-the-sound section at low tide and to determine the nutrient distribution along the shore from Hall Quarry to the mouth of Somes Harbor and along the west coast of Northeast Harbor. Shoreline stations were designed to sample conditions near the sewer outfalls for Somesville (located just north of Broad Cove) and Northeast Harbor (located north of the swimming pool). Station locations for Cruise II are illustrated in Figure 8.

Temperature and salinity data were obtained with a Beckman R-5 salinometer at nominal depths of: 0 (surface), 2, 4, 6, 8, 10, 15, 20, 25, 30, 35 and 40 meters, ending at the bottom when the depth was less than 40 meters. The salinity was calculated from the observed values of temperature and conductivity following the method of Lewis (1980). The sensitivity of the temperature and salinity results are $\pm$ 0.05°C and $\pm$ 0.05, respectively. In addition, surface temperature and a salinity sample were also obtained from a bucket sample at each station with the salinity sample being analyzed by Dr. Ted Loder, a marine chemist at the University of New Hampshire. At stations over 40 meters in depth, i.e. stations 6, 7, 8 and 9, a deep water sample was collected at two meters above the bottom with the temperature recorded immediately and the salinity and nutrient content analyzed in the same way as the surface samples discussed above.

The density of the sea water at each depth was calculated in terms of sigma-t[2] following the International Equations of State of Sea Water-1980 (Millero and Poison 1981). The following sections describe and discuss temperature, salinity and density

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2. Sigma-t is the value of the density of a sample of sea water at the observed temperature and salinity reduced by 1000. A sigma-t value of 22.82 (Cruise I, Station 1 at the surface) corresponds to a density value of 1022.82 kg/m^3. The use of sigma-t rather than density directly emphasizes the variations in density which are generally in the order of $\pm$ 0.1 percent.

results of each cruise. Nutrient data is presented in a later section beginning on page 19.

3.1 Data analysis

3.1.1 Cruise I

Figure 1 illustrates the station positions for the first cruise. The locations of four sections, one along-the-sound and three cross-sound, are illustrated in Figures 2a and 3. Each set of sections (Figs. 2b,c,d, 4, 5 and 6) illustrates the temperature, salinity and sigma-t structure of the sound along the indicated path. The along-the-sound section for Cruise I is sampled at the high tide section and is drawn from the head of Somes Harbor southwards toward the mouth of Somes Sound. The cross-sound sections are drawn from the western boundary of the sound toward the east. Vertical profiles of temperature, salinity and sigma-t for each station are plotted in Figures 7 (a to u) and the station data is tabulated in Table 1.

3.1.2 Cruise II

Figure 8 illustrates the station map for the second cruise. Vertical profiles for temperature, salinity and sigma-t were determined at stations 1 to 11, 14, 15 and 20. Surface values were obtained at the remaining stations, 11a to 11d, 15a to 15d and 20a. The low tide, along-the-sound sections for temperature, salinity and sigma-t are presented in Figures 9 (a-d). Vertical profiles of temperature, salinity and sigma-t for each station are plotted in Figures 10 (a-o) and station data is tabulated in Table 2.

3.2 Discussion of hydrographic results

The along-the-sound section for high tide (Fig. 2) indicates that most of the temperature and salinity variation occur in the upper 5 meters of the sound. Temperature generally changes by 2°C in the top 4 meters; however, the maximum variation was 2.3°C in the top 2 meters in Somes Harbor, station 1. Salinity generally varies by 0.75 in the upper 4 meters with a larger variation of 1.83 in the upper 4 meters in Somes Harbor, station 2. Surface salinity attains a minimum value of 29.23 near the head of Somes Harbor (stations 1 and 2) and increases to 30.86 just off of Greening Island (station 11). The water below 5 meters in depth is more uniform with values ranging between 3.4 to 5°C in temperature and 31 to 31.7 in salinity. This vertical variation is indicated clearly in the vertical profiles of each

station (Fig. 7). The sigma-t section also reflects this distribution in that the principal changes in density occur in the upper 5 meters; this indicates a fairly stable surface layer overriding deeper waters of more uniform density.

Figures 4, 5 and 6 illustrate the cross-sound sections for locations indicated in Figure 3. The surfaces of the cross-sound sections are curved to reflect variation in tidal height at the time each station was sampled. All of the cross-sound sections -- Valley Cove, Hall Quarry and Broad Cove -- illustrate that the fresher (less saline), warmer and less dense water has a tendency to lie along the western side of the sound with the denser and more saline water along the eastern side. The lowest salinity found on Cruise II was located just offshore of Hall Quarry (Fig. 5b). This overall salinity distribution supports the original suggestion by Folger et al (1972) that the residual (nontidal) circulation in the sound is counterclockwise.

The following table indicates the maximum, minimum and average values for the temperature, salinity and sigma-t from Cruise I.

	Average	Maximum	Minimum
Temperature	4.52	7.49	3.39
Salinity	31.10	31.75	27.94
Sigma-t	24.63	25.31	21.81

Data for the along-the-sound section at low tide (Fig. 9) indicates that the surface stratification so apparent in the high tide section disappears south of Broad Cove. In this region the temperature changes by a maximum of 2°C over the whole depth while the salinity changes by slightly more than 1 over the whole depth. Vertical profiles (Fig. 10) show very little variation for stations 5 to 11 along this section. The imprint of fresher water in Somes Harbor is visible in the along-the-sound sections from stations 1 to 4 (Fig. 9c) and appears as if a small plug of less saline water has moved out of the harbor during the tidal cycle.

The following table indicates the maximum, minimum and average values for the temperature, salinity and sigma-t from Cruise II.

	Average	Maximum	Minimum
Temperature	5.11	7.40	3.60
Salinity	31.23	31.79	29.44
Sigma-t	24.67	25.24	23.07

In comparing the results from the two cruises using primarily data from along-the-sound sections, it appears that the surface waters of the sound are strongly affected by the tidal cycle. The

surface layer stratification increases at high tide and decreases at low tide while the deeper water properties vary less with the tide. The temperature of the deepest waters at stations 8 and 9 increased by almost 0.5°C over the four-day interval. This increase may be due to a combination of tidal fluctuations and increased heating and mixing during the time interval between the two samples. The temperature increase does, however, indicate that a certain amount of mixing to 45 meters in depth occurred over this time period.

3.3 Additional summer and winter results

As a component of a summer graduate course at College of the Atlantic, students and C. Ketchum obtained hydrographic data at stations 2, 4, 6, 8, 9 and 11 (the along-the-sound section) near high tide on August 13, 1986. The data and analysis are presented in Appendix 1. The high tide, along-the-sound temperature section (Fig. A-1 b) is very similar to that of the spring section at high tide except that overall temperature values increased by about 9°C with the major variations in temperature occurring in the upper 5 meters. The summer salinity section (Fig. A-1 c) shows how little the salinity varies throughout the sound during the summer months. Previous work on the sound indicates the same type of minimal salinity variation for the summer months.

In collaboration with C. E. Parker and the Maine Department of Marine Resources, one of the authors (Ketchum) has also taken salinity and temperature values in the sound during the winter (February 17, 1982). The results indicates that both the temperature and salinity of the sound were quite uniform at that time. Winter temperatures were very low; the February 17 values varied from 0.14 to 0.56°C with a mean value of 0.27°C. and salinity varied from 30.47 to 31.82 with a mean value of 31.63.

4 Stream-flow measurements

Fresh water inflow into Somes Sound during the study period has been determined from drainage area calculations and stream-flow field studies conducted on March 29, April 2 and April 12. The primary streams that flow into the sound directly are Man-o-War Brook, Denning Brook (from Echo Lake), Somes Pond Stream, Babson and Kitteridge Brooks, three high school brooks, Richardson Brook, Southwest Valley Brook, Sargent Brook and Hadlock Brook. In addition several smaller streams drain the sides of Norumbega Mountain. Of all of these, we selected Hadlock, Southwest Valley, Sargent, Richardson, Babson, Somes Pond and Denning Brooks for field studies of actual stream flow.

Stream-flow measurements were accomplished in two ways: either by using a small drifter float (orange) and timing its travel over a known distance or, when the flow was sufficiently strong, by using a Beckman Flow Meter. Flow meter measurements were made at levels of 0.2 x depth and 0.8 x depth when stream depth was over 2.5 ft and at 0.6 depth when the stream was shallower. Results of field measurements of stream flow on March 29, April 2 and April 12 are tabulated in Table 3.

Figure 11 illustrates the daily rainfall recorded at Acadia National Park Headquarter's monitoring station for the 31 days prior to the April 15 cruise. It is quite clear that the stream-fow results from the March 29 field measurements represent the large stream flow following the 1.08 inch rainfall of the previous day. Measurements of April 2 reflect no additional rainfall while those of April 12 were completed in the rain and following a total rainfall of 1.54 inches over the previous 6 days. Variations in the stream-flow data reflect not only this pattern of rainfall, but also indicate that direct stream- flow measurements would need to be made quite frequently in order to provide a realistic estimate of the total fresh water flow into Somes Sound.

Since the circulation characteristics of the sound will naturally average out the daily variations in stream inflow, we can calculate the total inflow into the sound using drainage area estimates for each of the streams and ANP's rainfall data. While the rainfall over the study area may vary from that on McFarland Hill, the overall results using the drainage area calculations are likely to be much more appropriate than the relatively infrequent stream-flow measurements.

The drainage areas around Somes Sound can be separated into two groups: those that feed directly into the sound and those that feed a stream or brook draining into Somes Sound. Figure 12 shows the stream and direct drainage areas for Somes Sound. Regions labeled 1 to 9 represent stream drainage areas; those labeled 10 to 15 represent the direct drainage areas as considered in this phase of the study. Drainage area for Somes Pond was obtained from a letter from the Maine Department of Environmental Protection (Welch 1980). Other drainage areas were sketched on the Acadia National Park and Vicinity topographic map and determined by weight relative to a one-square-mile reference with a precision analytical balance. The resulting areas are listed as a component of Table 4.

All of the water falling on a drainage basin does not enter the stream flow directly. In general, a 50 percent run-off of rainfall is quite typical for Maine (Potvin 1984); Kane's (1984) summer study of Somes Pond also supports a 50 percent run-off figure. Runoff rates, however, are often affected by spring conditions when the ground is partially frozen and saturated by water from both rainfall and melting snow. These conditions can lead to an increased runoff rate. By focusing on the days

preceding the April 15 cruise, we can calculate various estimates of the average rain fall which in turn determines the stream flow into Somes Sound depending on the time interval used for the averaging. For example, the average rainfall over the preceding 7 days was 0.174 inches/day; however, if we extend the averaging interval to 8 days, we obtain a value of 0.190 inches per day. The results of using different averaging times are indicated below.

Averaging interval (days)	7	8	14	21	28
Rainfall (inches per day)	0.17	0.19	0.11	0.12	0.14

Table 4 shows the resulting stream flows as based on drainage area calculations for each of the above averaging intervals with a runoff rate of 50 percent.

Overall results indicate that drainage area calculations with a 50 percent runoff value underestimate the stream flow as compared to the field measurement results of Table 3. For example, the measured stream flow for Hadlock and Denning Brooks on March 29 is about one-third larger than estimated from the drainage calculations while those of Southwest Valley and Sargent Brooks are quite comparable. The April 12 measurements should correspond to the 7-or-8-day averages of Table 4 (Columns 4 and 5) with average rainfalls of 0.17 and 0.19 inches per day, but the field measurements indicate a greater flow rate for Hadlock, Denning and Richardson Brooks. This discrepancy is most likely due to the fact that during spring conditions, the ground is close to saturation from the snow melt and the 50 percent runoff figure is probably too low.

A more reasonable estimate of the runoff percentage can be found by combining the results of the field studies and the drainage area calculations. Table 3 indicates that four streams were studied on April 12 and Figure 11 illustrates the rainfall preceding these measurements. The average rainfall over the preceding six days was 0.26 inches per day. Table 5 illustrates the stream flow that would occur with a 100 percent runoff for this rate of precipitation. The ratio of the observed stream flow to that of the maximum possible provides a reasonable estimate of the runoff percentage. This value is listed in the last column in Table 5; the average runoff percentage is 66.2 percent.

5 Flushing rate calculations

One of the main goals of this study was to obtain an estimate of the spring flushing rate of Somes Sound. The flushing rate is the main measure used to estimate how frequently the water in the sound is mixed with and replaced by water from outside the sound.

This estimate also applies to any pollutant source that behaves physically and chemically like fresh water. The observed salinity of the sound water is used to estimate the fraction of fresh water that has been added to the salt water entering the mouth of the sound. Combining the results of all of the measurements leads to an estimate of the total amount of fresh water. The flushing rate is found by dividing the total amount of fresh water in the sound by the rate at which fresh water flows in from streams. The fresh water inflow rate is calculated from stream-flow measurements and drainage area calculations described in the previous section.

5.1 Fresh water content of the Somes Sound

The hydrographic results of the first cruise, April 15, provide vertical profiles of the salinity of the sound versus depth at 20 stations. The salinity at any particular station is determined from a mixture of fresh water from runoff and the saltier ocean water that enters the sound from the mouth. Observations at station 11, just beyond the mouth of the sound, suggest that the maximum salinity of ocean water entering the sound is 31.75. Using this value as the salinity of the primary salt water source, the mean fractional fresh water content, f_n, for a particular station depth with an observed salinity of S_n is then

$$f_n = (31.75 - S_n) / 31.75$$

The volume of fresh water, F_n, as indicated by each observation at a given depth and station is obtained by assigning a volume element, V_n, to each observation point and calculating the fresh water volume as

$$F_n = f_n V_n$$

The total fresh water in the sound at the time of the cruise is then found by adding all of the fresh water amounts as calculated for each observation.

5.1.1 Volume elements for Cruise I

Volume elements for each observation were obtained by segmenting the sound into 19 different sections, one for each station in the sound. The area sections for each station are illustrated in Figure 13. Area elements for each section were determined for each contour interval on a blown-up version of nautical chart 13318, i.e. for depths of 0 (mean low water), 6, 12, 18, 30, 60 and 120 feet. The charts also indicate the boundaries of the high tide. Thus, for each station, we obtained values for the area at high tide, low tide (0), and 6, 12, 18,

30, 60 and 120 feet in depth, stopping at the last contour depth at each station. The volume elements for a particular station are then obtained from the product of the average area of the upper and lower surfaces and the depth interval between them.

This process also provides a good estimate of the basic parameters of the sound defined as bounded at the mouth by the line between the southern ends of Fernald and Manchester Points and at the north by the culvert on route 198 that crosses the upper end of Somes Harbor. These results are:

Somes Sound Areas and Volumes

Area at high tide	8.050	km^2
Area at low tide	7.178	km^2
High tide volume	0.1214	km^3
Low tide volume	0.0968	km^3
Tidal prism	0.0246	km^3
Mean depth	13.5	m

Tidal prism represents the difference between high tide volume and low tide volume or the total volume added at each mean tide.

5.1.2 Fresh Water Content

The fresh water content of each volume element is obtained by finding the average salinity within each depth interval (high tide, 0, 6, 12, 18, 30, 60 and 120 feet) at each station, calculating the fractional fresh water content for the interval and forming the product of the fractional fresh water content and the volume element for that interval. The calculation begins at the upper surface which is set at the actual height of the surface above mean low water as calculated from the tide tables at the time of observation. The final results indicate that the total amount of fresh water in Somes Sound on April 15 was 1.782×10^{-3} km^3 or 1.782×10^{4} m^3.

This value is fairly sensitive to the value assumed for the salinity of the inflowing salt water that mixes with the fresh water runoff. In the above calculations this value was set to the maximum salinity observed at station 11 on April 15 (31.75). The table below illustrates some of the variation that might be expected with slightly different ocean water salinities.

Inflowing salinity	Fresh water volume (* 10^4 m^3)
31.70	1.617
31.75	1.782
31.80	1.946

The maximum salinity observed at station 11 on the second cruise was 31.79 and it seems likely that the actual value lies between 31.70 and 31.80.

5.2 Flushing rate calculations

Flushing time is defined as the time required to replace the existing fresh water in an estuary at a rate equal to the rate of input of fresh water into that estuary. A minimum estimate for the flushing time can be obtained by assuming that the water is completely mixed in each tidal cycle. The total volume of water introduced in each tidal cycle is known as the tidal prism, and under the above assumptions the flushing time would be equal to the total high tide volume of the sound divided by the tidal prism. Using the values from the previous section on volume elements, page 10, we find a minimum flushing time of 4.93 (=0.1214/0.0246) tidal cycles or approximately 2.5 days. We must emphasize that this simple estimate almost always underestimates the actual flushing rate because the mixing during a tidal cycle is not complete.

The results for stream-flow measurements, page 6, and fresh water content of the sound, page 10, enable us to calculate the flushing time directly. Data taken on the first cruise indicate that the maximum salinity of the inflowing salt water at the mouth of the sound is 31.75 which leads to a total fresh water content of 1.782×10^4 m^3. Flushing time is then the total fresh water volume of the sound divided by the fresh water input.

The most direct procedure to calculate the fresh water inflow into Somes Sound involves using the total rainfall for a given day and calculating the runoff produced using the drainage area values and the estimated runoff percentage (Fig. 14 and Table 6). Table 6 illustrates the results of this calculation for 5, 6, 7, 8, 9 and 10 days prior to the April 15 cruise with a runoff percentage of 66 percent as indicated by the stream-flow studies. The last line in this table indicates the total accumulation of fresh water in the sound using the above runoff values. The 1.782 in the second line from the bottom is the observed volume ($\times 10^4 m^3$) of fresh water in the sound under the above assumptions. Flushing time is that time needed for the accumulated runoff water volume to equal the volume of fresh water in the sound. The last two lines of the table, labeled "Volume of fresh water in the sound" and "Accumulated total

inflow", indicate that the accumulated inflow into is equal to the volume of fresh water in the sound at a time between 7 and 8 days. Figure 14 illustrates these results graphically: the horizontal line labeled "Fresh Water Content of the Sound" is the $1.782 \times 10^{4} m^{3}$ fresh water volume and the line labeled "Runoff accumulation" represents the total fresh water accumulation from all of the streams, direct drainage areas and the sound itself. The flushing time corresponds to the time at which the two lines cross or near 7.5 days.

The estimated volume of fresh water flowing into the sound from runoff and direct precipitation is sensitive to the assumed value of the runoff percentage. Figures 15a and b illustrate the results using 50 percent and 70 percent as runoff percentages, respectively. The results with a 50 percent runoff indicate a flushing time of 17 days while those using a 70 percent runoff indicate a flushing time nearer 7 days. Since 50 percent runoff is a reasonable year round value for our area, we can consider the 17-day estimate as an upper limit to the flushing time of Somes Sound.

The volume of fresh water in the sound as calculated from the salinity data is sensitive to the salinity value assumed for the salt water source. Page 11 indicates the differing volumes attained using input salinities of 31.70 and 31.80. Figures 16a and b illustrate the variations in flushing time introduced by the above salinities using the 66 percent runoff figure. The flushing time varies between 7 and 8 days.

These results can be summarized as follows:

Runoff Percentage	Input Salinity	Flushing Time
66%	31.75	7.5 days
50%	31.75	17 days max
70%	31.75	7 days
66%	31.70	7 days
66%	31.80	8 days

Since the rainfall from a given storm is generally drained off over a period of several days, the 17-day maximum is probably too high even if the runoff percentage in the spring were as low as 50 percent. In summary, the results seem to indicate a flushing time between 7 and 8 days with an upper limit of 17 days. Allowing for the above variations, it seems reasonable to set a value of 8 days for the flushing time.

6 Chemical composition of inflowing streams

Another goal of this study was to determine the chemical composition of streams flowing into Somes Sound during the spring when the additional pressure of summer visitors and residents is minimal. Thirteen streams were analyzed between June 2 and June 10 1986. The analysis measured 1) phosphorus as orthophosphate and total phosphate, 2) nitrogen as ammonia and nitrate and 3) silica, aluminum, pH , stream conductivity and chemical oxygen demand.

Both phosphorus and nitrogen are generally limiting nutrients that determine the degree of biological growth in oceanic and fresh waters. Phosphorus, however, tends to be the limiting nutrient in fresh water lakes while nitrogen is more likely to be the limiting nutrient in coastal waters and estuaries (Ryther and Dunstan 1971) including Somes Sound. In natural waters, phosphorus may be present as orthophosphate (PO_4^{-3}) as well as more complex inorganic and organic forms. Determination of total phosphate indicates the total concentration of all forms. Nitrogen occurs naturally in three forms: ammonia (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). Ammonia, the primary form of nitrogen in secondary sewage effluent, oxidizes readily to nitrite and then to nitrate within natural bodies of water. Silica (SiO_2) is another nutrient that may be limiting in terms of plankton growth in special cases and high aluminum concentrations are quite often toxic to fish. pH determines the free acidity of the stream and stream conductivity serves as a measure of the total dissolved salts. High conductivity levels in fresh water streams are an indication of possible pollution. Finally, the chemical oxygen demand (COD) is a measure of the total amount of organic matter in the flow.

The following subsections describe some of the key results of two previous studies of precipitation and stream composition, explain the methods used in the above-mentioned determinations and present the main results of this study.

6.1 Previous work on Mount Desert Island

During 1983 and 1984, the National Park Service completed an extensive study (hereafter referred to as ANP) of lakes and streams within its jurisdiction. Monthly variations of conductivity, aluminum, nitrate and pH are illustrated in Figure 17 for two of the streams in the ANP study, Heath Brook and Hadlock Brook, both of which feed into Somes Sound.

As a part of the Institute for Ecosystems Studies Cloud Water Program (hereafter referred to as IES), a fairly complete analysis of rain and fog samples was completed during the summers

of 1984 and 1985. Figure 18 presents the average and extreme rain compositions obtained in July 1984 for the IES study. Figure 19 depicts the changes in pH and conductivity that occur between direct precipitation and stream water for Hadlock and Heath Brooks as indicated by the combined results of the ANP and IES studies.

Streams consistently have pH values of 1-1.5 units higher than incident rain and, except in July, stream pH values parallel changes in rain pH indicating that free hydrogen ion activity, $[H^+]$, as indicated by low pH, is less concentrated in streams than in rain. Since it seems unlikely that rain is diluted by another source of less acidic water, such as deep ground water, the H^+ is probably trapped on its way to the stream. The rise in stream pH during July, when rain pH dropped, suggests the appearance of some neutralizing factor during July.

In mid-March, stream conductivities were about equal to rain, but were 2-3 times greater in February and 7-8 times greater in October. These higher conductivities indicate either the dissolution of more material in the runoff water or a loss of water by evaporation, transpiration or deep seepage as rain travels to streams. While transpiration should drop in cold weather, the extent to which evaporation is a factor depends on the counteracting effects of lower humidity and lower temperatures.

The ANP and IES studies also analyzed rainfall and stream concentrations for calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^+), sodium (Na^+), sulfate (SO_4^{-2}), nitrate (NO_3^-) and chlorine (Cl^-). Some of these results for July, 1984 are presented in Figure 20 and summarized below.

1. Compared to the incident rain, the streams have higher concentrations of Na^+, Cl^-, Mg^{+2} and Ca^{+2}. Salt (NaCl), is probably deposited as ocean spray and mist into the watershed and then washed out by rain to the streams. Ca^{+2} and Mg^{+2} are presumably displaced from soils by incident H^+.

2. Compared to the incident rain, streams have lower concentration of nitrate (NO_3^-). Incident nitrate is apparently taken up by surrounding life forms.

3. In Heath Brook the concentration of sulfate is equal to that of precipitation; this suggests that sulfate flows passively through soil. However, the higher concentration of sulfate in Hadlock Brook over that of precipitation suggests the presence of an additional sulfate source in that watershed.

6.2 Methods and procedures

Chemical analyses for stream flow were done from June 2 - June 10, 1986, specifically on June 2, 3, 9 and 10. On-site estimates of stream flow as indicated by stream depth suggests that the flow rate in streams was largest on June 2 and least on June 10 with flow rates on June 9 larger than on June 3.

The survey covered the major streams flowing directly into Somes Sound. The table below assigns a key letter sequence that represents each stream studied. The location and drainage region of each stream is indicated in Figure 21 as identified by the key letter sequence.

Major Streams Studied
Streams included in the figures

Denning Brook		D	Outflow from Echo Lake
Somes Pond Outflow		SP	Somes Pond drainage
Babson and Kitteridge		KB	
High School	West	HSW	Western Stream
	Central	HSC	Center Stream
	East	HSE	Eastern Stream
Heath and Richardson		HR	
Southwest Valley		SW	
Sargent Brook		S	
Norumbega Brook		N	
Hadlock Brook		HD	Drains Hadlock ponds

Additional measurements were taken at

Sand Pile Brook	SP	Drains the area near the Northeast Harbor sand pile
Boatyard	BY	Near the boatyard off Sargent Drive

Conductivity and pH results were determined from unfiltered stream samples in the field. Conductivity was measured with a Hach conductivity meter (0-100 umho/cm full scale) and pH with an Orion pH meter following calibration with buffers of pH 7 and pH 4. Following filtering through 0.45u Millipore filters to remove suspended matter, we used standard colorimetric tests (Hach Chemical Co.) to measure aluminum (Al^{+3}), silica (SiO_2), orthophosphate (PO_4^{-3}), total phosphate, nitrate (NO_3^-), ammonia (NH_4^+) and chemical oxygen demand (COD).

For the silica and phosphate tests to be on scale, samples often needed to be diluted. Ammonia was measured with reagents prepared in accordance with instructions in the 13th edition of

Standard Methods for the Examination of Water and Waste Water and used with the Hach colorimeter scale following calibration with Hach ammonia standards. Random samples were repeated to check reproducibility. Results of the repeated test in terms of the observed deviations are illustrated below.

Test Results [ppm]

Aluminum	Maximum variation ± 0.015
Silicate	Maximum variation ± 0.15
Orthophosphate	Maximum variation ± 0.25
Total Phosphate	Maximum variation ± 0.2
Nitrate	Maximum variation ± 0.35
Ammonia	Maximum variation ± 0.032

Results of all stream analyses are presented in Table 7 and results for each particular constituent are described in the following sections.

6.3 Phosphate

Due to low solubility of various forms of phosphate, it is often a limiting nutrient in fresh water systems. Phosphate results for all streams are presented in Table 7 and summarized graphically in Figures 22a and b. These figures illustrate the proportion of total phosphate that occurs in terms of orthophosphate and other forms. At times of low and high flow, there is a significant difference between stream concentration with the highest concentrations occurring at low flow. During low flow the proportion of orthophosphate and other forms is roughly equal except for West High School, Heath and Hadlock Streams where orthophosphate predominates. At high flow, orthophosphate predominates for all of the high school streams as well as Southwest Valley, Norumbega and Hadlock Streams; other forms of phosphate are dominant at Denning, Somes Pond and Heath Streams. These observations suggest that the phosphate sources in all but the Southwest Valley and Norumbega watersheds are constant; the Southwest Valley and Norumbega watersheds, however, have phosphate sources which are mainly flooded at high water.

For streams with similar characteristics as those flowing into Somes Sound, typical values have been determined from studies at Hubbard Brook in the White Mountains of New Hampshire (Likens et al 1978). In streams feeding Somes Sound, orthophosphate ranges from 4 - 100 percent of total phosphate, with an average of 53 percent. In comparison to typical waters, this figure is high and suggests the presence of substantial sources of orthophosphate. The greatest percentages of orthophosphate are found in Hadlock, the high school drainages and, at high flow, in Southwest Valley and Norumbega drainages.

The overall range for orthophosphate for streams in this study is 0.02 to 7.95 [ppm] with a mean of 2.66 ± 2.09 [ppm]. This mean value is three orders of magnitude greater than concentrations (0.0029) found in Hubbard Brook and in excess of two orders of magnitude higher than that found in average river water. Total phosphate has a range of 0.5 to 12.0 [ppm] with a mean value of 4.42 ± 2.96 [ppm]. For comparison, consider that pure water standards for drinking water are 0.01 to 0.05 [ppm] (Horne 1978) and secondary sewage effluent has from 17 to 25 [ppm] (PO_4^{-3}) (Horne 1978 and Champ 1975).

6.4 Nitrogen

Nitrogen is of concern for it is often the limiting nutrient controlling phytoplankton growth in marine waters (Ryther and Dunstan 1971). Nitrogen enters natural water principally from decaying organic matter, from deposition of nitrate (NO_3^-) and ammonia (NH_4^+) in rain, fog and dust and from the use of nitrogen fertilizers. Ammonia is oxidized by bacteria to nitrite (NO_2^-) and finally to nitrate (NO_3^-). Because nitrite is rapidly oxidized to nitrate, it is seldom found in detectable concentrations in aerated waters.

The results of the spring analyses for nitrate and ammonia are listed in Table 7 and illustrated in Figures 23a and b. Nitrate concentrations range from 0 to 17.5 [ppm] with an average of 5.94 ± 3.40 [ppm]. Ammonia concentrations range from 0.05 to 2.83 [ppm] with an average of 0.72 ± 0.59.

Nitrate concentrations in the Boatyard, Heath and Richardson, Sargent, and Southwest Valley Brooks and all three high school streams increases with increasing flow rate while the concentrations in the other streams remain almost constant. The high school streams have the highest concentrations with maximum values of 17.49 and 14.39 at high flow rates.

Like nitrate, ammonia is highest (2 to 2.83 [ppm]) at high flow at the high school (all three streams), although nearby streams (Heath, Southwest and Norumbega) are also relatively high (1.4 [ppm]). As with nitrate, these concentrations dropped as flow lessened. Unlike nitrate, however, they did not rise again during the next rain, possibly because it takes more time to replenish leachable ammonia than nitrate.

These results are compared in Table 8 to nitrogen concentrations in fog, rain and streams on Mount Desert Island (ANP and IES) and at the Hubbard Brook Experimental Forest in New Hampshire. Figure 24 illustrates some of the variation found by the ANP study for 1983 and 1984. Hubbard Brook and earlier Acadia National Park Stream results have much less nitrate than rain, whereas our values are approximately the same as rain. With the exception of Stanley Brook (in Seal Harbor), the ANP study found

no significant concentrations of nitrate in streams in June, and the values for Hubbard Brook in June are lower than at other times. This suggests that our results for June represent low values in terms of a yearly average. Our results indicate that nitrate is the dominant form (average values of 1.34 [ppm] nitrogen in nitrate versus 0.56 [ppm] nitrogen in ammonia) of nitrogen in the streams draining into Somes Sound; the concentrations are substantially higher than those obtained in the 1983-84 IES study for June and are almost twice that of the July, 1983 results from the ANP study. Ammonia follows a similar pattern as nitrogen with the highest concentrations occurring in fog and the least in stream flow. The mean ammonia concentration of the study streams around Somes Sound is more than an order of magnitude higher than that at Hubbard Brook.

6.5 Silica

Stream-flow concentrations for silica (SiO_2) are listed in Table 7 and illustrated for low and medium flow conditions in Figure 25. Silica concentrations averaged 3.25 ± 2.13 [ppm] over all of the streams and flow conditions. The highest concentrations in Figure 25 (5 to 7 [ppm]) occur in the high school streams at medium flow. Higher values (8 to 9 [ppm]) were found at high flow rates in West High School, Southwest Valley and Boatyard Streams.

6.6 Conductivity

Conductivity results are listed in Table 7 and illustrated in Figure 26. The stream with the highest conductivity was that next to the highway garage on Sargent Drive, presumably reflecting loss from their salt storage. Other streams show conductivities typical of streams on granite. Average stream conductivity (60.6 umho/cm) is slightly more than average rain conductivity (42.2 umho/cm), indicating that rainwater does pick up more salts as it flows from streams.

6.7 pH

Values for local pH are listed in Table 7 and illustrated in Figure 27. Low pH values indicate more acidic conditions. On Mount Desert Island, fog has an average pH of 3.55 while rain has a average of 4.4. The Central and East High School Streams have the lowest pH with an average of 4.66 as compared to an average of 6.1 for all of the other streams in this study. All stream pH values are higher than those of the average rainfall indicating that the incident acidity of rainfall is neutralized slightly

before it reaches the streams. pH levels increase with large flow rates.

Figure 28 illustrates the variation of aluminum concentration with pH. In general, decreased pH levels lead to increases in the aluminum concentration of the streams.

6.8 Chemical oxygen demand

Chemical oxygen demand (COD) expresses the total amount of oxygen in [ppm] that would be used to oxidize all oxidizable material in a sample. Extremely high values of COD can indicate the possibility of anoxic conditions, a state of very low oxygen values in the water. Because, the analysis for determining the COD is time consuming, it was completed on a selected number of samples rather than done routinely. Results are listed in Table 7 and illustrated in Figure 29. Moreover, no obvious correlations between stream color and COD were observed. The highest levels of COD occur in the Somes Pond Overflow and in Norumbega Stream followed by Denning Brook and the high school streams. Sargent Brook has the lowest values. COD decreases as flow increases.

7 Phosphate and sulfate in Somes Sound

On each of the spring sampling cruises, we collected surface water samples for phosphate (orthophosphate and total phosphate) and sulfate analyses. Deep samples were also taken at two meters off the bottom in the four deep holes at stations 6, 7, 8 and 9. The station positions for the April 15 cruise are shown in Figure 1 and those for April 19 in Figure 8. In order to sample possible effects of the two secondary sewage treatment outflows into the region of the Sound, we collected on the second cruise (April 19) a series of surface samples along the shore from Hall Quarry to beyond Broad Cove (stations 15a to 15d) and from Manchester Point to Gilpatrick Cove (stations 11a to 11d) in Northeast Harbor. The results of the analysis, listed in Tables 9a and b, are discussed below.

7.1 Phosphate

Surface distributions of orthophosphate and total phosphate in [ppm] are presented in Figures 30a-b and 31a-b, respectively. The left side of each figure corresponds to values obtained near high tide on April 15 and the right side to values obtained near low tide on the April 19 cruise.

Orthophosphate

High tide, April 15: Concentrations average 0.09 [ppm] and rise to 0.1 [ppm] near the north shore. The maximum concentration of 0.88 [ppm] is found in Valley Cove.

Low tide, April 19: Concentrations of 0.10 [ppm] are more widespread at low tide than at high tide with values rising to 0.2 [ppm] near the north shore. Concentrations are also relatively high (0.12 to 0.16 [ppm]) along the shore of Hall Quarry northwards to Broad Cove and from Valley Cove southwards to beyond Smallidge Point. The high concentration of 0.88 [ppm] found on April 15 in Valley Cove is no longer present.

Total phosphate

High tide, April 15: Concentrations average 0.82 [ppm] with the highest concentrations (2.5 to 2.8 [ppm]) over the deeper holes at stations 6 and 7.

Low tide, April 19: Concentrations average 0.44 [ppm] with the highest concentrations (1.2 to 1.5 [ppm]) found along the shore at Hall Quarry and in Somes Harbor.

The major source of orthophosphate appears to be on or near the shore especially near Hall Quarry. Near low tide, but not at high tide, the shore also appears to be the source of total phosphate. Highest values of total phosphate (2.3 to 2.5 [ppm]) occur at high tide in mid-sound off of Acadia Mountain (stations 6 and 7).

The analysis of samples taken two meters off the bottom in each of the four holes is presented below.

Orthophosphate					
Station	6	7	8	9	
High tide	0.02	0.02	0.02	0.02	[ppm]
Low tide	0.20	0.08	0.05	0.08	[ppm]

Total Phosphate					
Station	6	7	8	9	
High tide	0.15	2.25	1.00	0.40	[ppm]
Low tide	1.90	0.15	0.35	0.17	[ppm]

The deep spots seem to contain a significantly large portion of total phosphate over orthophosphate with station 7 containing the highest concentration at high tide. Variations in concentrations between high and low tide for total phosphate would indicate that the deep portions are fairly effectively flushed over the time span of the two cruises -- four days.

The results of our study are comparable to those obtained by Gilmartin (1981) for orthophosphate.

Location	Off Hall Quarry	Off Valley Cove	
Depth			
0	0.004	0.049	[ppm]
10	0.063		
20	0.090		
30		0.078	
45		0.065	

7.2 Sulfate

Folger et al (1972) suggested the possible presence of hydrogen sulfide in the sediments of the northern regions of Somes Sound. This suggestion led us to determine sulfate concentrations on the collected samples for the first cruise. Sulfate concentrations were determined by both direct measurement and from standard addition measurements. The results are listed in Table 9 and a contour plot is presented in Figure 32. The average concentration as determined by the direct method is 1788 ± 177 [ppm] and from the standard addition method it is 1548 ± 362 [ppm]. Both determinations suggest relatively low sulfur concentrations in Somes Harbor and the possibility of a sulfate source in the northeast corner of the sound.

7.3 Oxygen

Due to equipment failure, oxygen was not measured on either of the spring cruises. Oxygen was, however, sampled on the August 31 cruise in the northern section of the sound by Ketchum, and the values indicate that the deeper waters of the sound are

definitely not anoxic although oxygen values do drop rapidly as the probe enters some of the sediments. This latter point may indicate anoxic sediments. These results will be described in a later report. In addition, Gilmartin (1986) has provided some oxygen values obtained during 1981 and 1982 (Table 10). None of the data in the table indicate anoxic conditions and most of the water is at least 50 percent saturated in oxygen.

8 Discussion of results

8.1 Temperature and salinity

The temperature and salinity studies within the sound indicate that at high tide, the first five meters of the sound are more strongly stratified than the deeper waters, whereas at low tide the stratification seems to be more uniform with depth. This reduction of stratification over the tide cycle will serve to enhance the mixing processes within the sound. The summer results for high tide indicate that while the mean temperature of sound waters increased by about 9°C from April 15, the temperature stratification has the same magnitude as that observed in the spring. Salinity variations in the spring indicate the clear presence of fresh water mixing; weak variations in salinity in summer, on the other hand, reflect a decrease in fresh water input.

8.2 Flushing rate

Flushing rate calculations indicate an 8-day flushing time with an upper maximum of 17 days. The 8-day estimate is derived by considering variations in runoff percentages and salinity of the salt water source. This value is several days longer than estimated for other estuaries with significantly larger fresh water inputs. The Mersey Narrows in England, for example, has an estimated flushing time of 5.3 days, the Columbia River from 1 to 5 days and the New York Bight from 6 to 10.6 days (Dyer 1973).

8.3 Nutrients in runoff

The range of orthophosphate concentrations observed in the streams in June extends from 0.02 to 7.95 [ppm] with a mean value of 2.66 [ppm]. Total phosphate concentrations range from 0.5 to 12.0 [ppm] with a mean value of 4.42 [ppm]. These total phosphate concentrations are significantly higher than those reported for streams in the White Mountains of New Hampshire. In addition, streams feeding into Somes Sound have a higher percentage of orthophosphate than similar stream in the White

Mountains. Nitrogen concentrations have been determined in terms of nitrate and ammonia concentrations in the streams. Nitrate concentrations range from 0 to 17.4 [ppm] with an average value of 5.94 [ppm]. Ammonia concentrations range from 0.05 to 2.83 [ppm] with an average value of 0.72 [ppm]. The nitrate and ammonia concentrations generally increase with stream flow. Both nitrate and ammonia concentrations are relatively high in the three high school streams, but one must remember that the high school streams contribute only 3.1 percent of the total stream fresh water input to Somes Sound. We calculate the total nitrogen input to the sound via the streams and direct drainage (see discussion below) to be 182 kg/day of nitrogen in nitrate (NO_3^-) and 76 kg/day of nitrogen in ammonia (NH_4^+) and taking the high concentrations from the high school streams as an average of the two highest values i.e. 15.94 [ppm] nitrate and 2.44 [ppm] ammonia, we find that the daily input from the high school streams is only 15 kg/day of nitrogen versus a total 182 kg/day from nitrate in natural drainage and 6.7 kg/day of nitrogen versus a total of 76 kg/day form ammonia in natural drainage. Thus, these streams will contribute at most 8 percent of the nitrogen input to the sound.

8.4 Nutrient concentration in Somes Sound

The stream-flow concentrations can be used to calculate the total amount of phosphate and nitrogen carried into the sound by runoff. The average rainfall for the region as calculated from data spanning the eight years from 1972 to 1979 is 0.146 inches per day. This value leads to a total stream flow, using a normal yearly runoff percentage of 50 percent, of 113 x 10^6 liters/day and 23 x 10^6 liters/day for the direct runoff for a total average runoff of 136 x 10^6 liters/day. Combining this flow rate with the average concentrations found in the streams (Table 7), we find the following daily loading rates:

OrthoPhosphate	Phosphorus
361 kg PO_4^{-3}	117 kg-P
Total Phosphate	
601 kg T-PO_4^{-3}	196 kg-P
Nitrate	Nitrogen
805 kg NO_3^-	182 kg-N
Ammonia	
98 kg NH_4^+	76 kg-N

Thus, streams and direct drainage carry an average of 196 kg of phosphorus and 258 kg of nitrogen per day into Somes Sound.

The fraction of orthophosphate concentration in Somes Sound due to runoff can be estimated using the above values. Assuming that because of an 8-day flushing rate concentrations will remain in the sound for 8 days, the total phosphate input into the sound is 2,888 kg (PO_4^{-3}) which if mixed over the low tide volume of the sound of 96.8×10^4 m^3 leads to a concentration of 0.03 mg/liter or about 30 percent of the observed concentration. The same process can be used to calculate the nitrogen concentration in terms of nitrate. If we assume that all of the nitrogen flowing into the sound is oxidized to nitrate and calculate the nitrate concentration from this assumption, 258 kg of nitrogen flow into the sound daily; this is equal to 1,142 kg of nitrate when all of the ammonia has been oxidized to nitrate. This leads to an average concentration in the sound of 0.159 mg/liter. If none of the ammonia is oxidized over the period of 8 days, the nitrate concentration would be nearer 0.066 mg/liter. Nitrate concentrations in the eutrophic Delaware River (Lipschultz et al 1986) are on the order of 25 times this concentration.

8.5 Secondary sewer inputs

There are two secondary sewer treatment facilities with outfalls located in or near Somes Sound. The Somesville outfall is located north of Broad Cove and runs offshore to a depth of 1.5 meters at low tide. The end of the pipe is clearly visible at low tide under the water. The summer operating capacity of the Somesville treatment facility is 15,000 gallons per day. The Northeast Harbor facility runs offshore toward Southwest Harbor from a point north of the swimming pool at the Northeast Harbor Tennis Club along a path quite visible at low tide between Manchester and Smallidge Points. This outfall is located near the mouth of our definition of Somes Sound and has a summer operating capacity of 150,000 gallons per day. Direct measurements of the nutrient concentrations in the immediate vicinity of the Somesville outfall were collected on August 31, 1986 and will be reported on in a later report. In addition, D. Cass has recently analyzed concentrations from samples from each of the sewar effluents collected on September 26, 1986. These values are reported below:

Effluent concentrations

Species	Norhteast Harbor	Somesville
Orthophosphate	14.0 [ppm]	14.0 [ppm]
Total Phosphate	47.5 [ppm]	30.0 [ppm]
Nitrate	33.2 [ppm]	5.7 [ppm]
Amonia	0.26 [ppm]	0.38 [ppm]

The total sewer inflow is 165,000 gallons per day or 0.627 x 10^4 liters per day. Both Horn (1978) and Champ (1975) provide typical concentration of nitrogen and phosphate in treated effluent. The table below compares the total effluent input to that of all of the stream and direct drainage values listed above.

Effluent Concentration		Effluent Input	Natural Drainage Input
Phosphate			
25 [ppm]	Horn(1978)	15.6 kg/day	601 kg/day
16.9 [ppm]	Champ(1975)	10.6 kg/day	
47.5 [ppm]	Cass	30.0 kg/day	
Nitrate			
17.3 [ppm]	Champ(1975)	10.8 kg/day	805 kg/day
15 [ppm]	Horn(1978)	9.4 kg/day	
33.2 [ppm]	Cass	20.8	
Ammonia			
20 [ppm]	Horn(1978)	12.5 kg/day	98 kg/day
0.38 [ppm]	Cass	0.24 kg/day	

The total sewage effluent input is on the order of 5 percent for phosphate and 3 percent for nitrate of the natural input into Somes Sound except for the ammonia which, using the highest value in the above table, may be on the order of 16 percent but it is less than 1 percent as determined from direct measurements. If we convert the ammonia and nitrate to nitrogen values, we find the sewer effluent may contribute up to 14.4 kg of nitrogen per day versus the 258 kg of nitrogen contributed by natural drainage.

8.6 Suggestions for future work

This report is designed as a preliminary study of Somes Sound during a time when the increased summer population has little direct influence on the natural characteristics of the water. The initial results indicate that the sound has a good flushing rate and there are no major indications of deleterious inputs from local streams and drainage areas. The nutrient study carried out on August 31 will provide more detailed information on the concentrations of nutrients in the northern region of the sound and near the Somesville sewer outfall. When that study is completed, both reports should be circulated to key professionals within Maine for review with a special focus on highlighting any areas of specific concern that have escaped the present authors' recognition. In particular, Dr. Chris Garside of Bigelow Laboratory for Ocean Science, a marine chemist, and Mr. Charlie

Parker, a physical oceanographer from Boothbay Harbor, could be asked to review the work. In addition, Andrew Smith of the Natural Resource Council of Maine and Anne Johnson of Maine Audubon have areas of expertise directly related to the concerns of this study.

The next phase of the study, if warranted as based on the above reviews and a continuing concern, would be to carry out a detailed study of the nutrient distribution within Somes Sound during the summer when the population pressure within and around the sound is at a maximum. It seems clear that the nitrogen budget of the sound would be the prime focus of such a nutrient study.

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Somes Sound Spring 1986 Study

Part 2

Figures, Tables and Appendix

Prepared for

The Somes Sound Association

and

The Town Of Mt. Desert

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By Carl B. Ketchum, Ph.D.
Physical Oceanographer
College of The Atlantic

and

Donald Cass, Ph.D.
Chemist
College of The Atlantic

10 Figure Legends

Figure 1. Station map for the April 15, 1986 data cruise -- Cruise I.

Figure 2. High tide along-the-sound section for the April 15 cruise. a. Location of the along-the-sound section, b. Along-the-sound temperature section, c. Along-the-sound salinity section, d. Along-the-sound sigma-t (density) section. Somes Harbor is located at the far left of the section.

Figure 3. Station map illustrating the locations of the three cross-sound sections for Cruise I.

Figure 4. Cross-sound section profiles for temperature, salinity and sigma-t beginning at Valley Cove on the left of figure.

Figure 5. Cross-sound section profiles for temperature, salinity and sigma-t beginning at Hall Quarry on the left of figure.

Figure 6. Cross-sound section profiles for temperature, salinity and sigma-t beginning at Broad Cove on the left of figure.

Figure 7(a-u). Vertical profiles for temperature (T), salinity (S) and sigma-t (*) for each station for the April 15, 1986 cruise.

Figure 8. Station map for the second cruise on April 19, 1986 -- Cruise II.

Figure 9. Low tide along-the-sound section for the April 19 cruise. a. Location of the along-the-sound section, b. Along-the-sound temperature section, c. Along-the-sound salinity section, d. Along-the-sound sigma-t (density) section. Somes Harbor is located at the far left of the section.

Figure 10(a-o). Vertical profiles for temperature (T), salinity (S) and sigma-t (*) for each station for the April 19, 1986 cruise.

Figure 11. Rainfall distribution as recorded at Acadia National Park Headquarters on McFarland Hill over the duration of the study period.

Figure 12. Somes Sound drainage areas. The numbers on each area are keyed to the values recorded in Tables 4 and 6. Numbers 1 to 9 represent stream flow drainage areas. Numbers 10 to 15 represent areas considered as draining directly into Somes Sound and number 16 represents Somes Sound proper.

Figure 13. The area elements considered in calculating the total amount of fresh water in Somes Sound on April 15.

Figure 14. Flushing time estimate for a 66 percent runoff percentage with the salt water source having a salinity of 31.75. The straight horizontal line represents the total fresh water content of Somes Sound on April 15 and the second curve represents the total accumulation of fresh water in the Sound due to runoff and direct precipitation over the number of days prior to April 15. Flushing time is indicated by the crossing point of the two lines near 7.5 days, when the total accumulation of fresh water from runoff is equal to the April 15 fresh water content of the sound.

Figure 15a and b. Flushing time results for a 50 percent (a) and 70 (b) percent runoff figure with an in flowing salinity of 31.75.

Figure 16a and b. Flushing time results for a 66 percent run off figure when the in flowing salinity is 31.70 (a) and 31.80 (b).

Figure 17 a and b. Monthly data collected by ANP for Heath and Hadlock Brooks on Mount Desert Island.

Figure 18. Rain extremes and averages observed during July 1884 IES study on Mount Desert Island.

Figure 19 a and b. Depicting the changes in pH and conductivity between that occur between direct precipitation and stream water for Heath and Hadlock Brooks as indicated by the combined results of the ANP and IES studies.

Figure 20. ph and concentrations for calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^{+}), sodium (Na^{+}), sulfate (SO_4^{-2}), nitrate (NO_3^{-}) and chlorine (Cl^{-}) from July, 1984 (IES and ANP).

Figure 21 Drainage area map and stream locations for field studies in June, 1986. Streams are identified by key letters listed in the table on page 15.

Figure 22a and b. Phosphate concentrations for selected streams in June 1986. Streams are identified by key letters listed in the table on page 15.

Figure 23a and b. Nitrate (a) and ammonia (b) concentrations for selected streams in June, 1986. Streams are identified by key letters listed in the table on page 15.

Figure 24 Nitrate levels as observed by ANP over the years 1983 to 1984.

Figure 25. Silica concentrations in selected streams for June, 1986. Streams are identified by key letters listed in the table on page 15.

Figure 26. Conductivity of local streams as measured in June, 1986. Streams are identified by key letters listed in the table on page 15.

Figure 27. pH of selected streams as measured in June, 1986. Streams are identified by key letters listed in the table on page 15.

Figure 28. Variation of aluminum [Al] concentration with pH from the June studies.

Figure 29. Chemical oxygen demand in selected streams for the June, 1986 study. Streams are identified by key letters listed in the table on page 15.

Figure 30a and b. Orthophosphate concentrations observed in Somes Sound for high tide on April 15 (a) and for low tide on April 19 (b). Concentrations are expressed in [ppm].

Figure 31a and b. Phosphate concentrations observed in Somes Sound for high tide on April 15 (a) and for low tide on April 19 (b). Concentrations are expressed in [ppm].

11 Table Legends

Table 1. Temperature, salinity and sigma-t (density) values for the April 15, 1986 cruise.

Table 2. Temperature, salinity and sigma-t (density) values for the April 19, 1986 cruise.

Table 3. Stream-flow measurements made in the field. The values determined using the float method are based on the time it takes several floats to traverse a fixed distance in the stream. The meter method used a Beckman Flow meter.

Table 4. A sample of stream-flow estimates calculated from the drainage area (3rd column), a given rainfall rate and runoff percentage. The average rainfall is determined from the total rainfall over the number of days prior to April 15. The number under the map region identifies the area located in Figure 12. Flow rates are recorded in cubic feet per second.

Table 5. Calculated and average runoff percentages for local streams during the six days preceding the stream flow measurements on April 12. The second column of numbers represents the total flow that would be observed with a 100 percent runoff percentage. The last column represents the actual percentage observed.

Table 6. Illustrating the calculation of the total accumulation of fresh water in Somes Sound from runoff assuming that all of the rain falling on a given day directly enters the sound in a proportion indicated by the runoff percentage. The runoff percentage is set to 66 percent as indicated by the results in Table 5. The next to last line of numbers from the bottom indicates the volume of fresh water in the sound as found on April 15. The last line indicates the total accumulation of fresh water from runoff. The flushing time is the time necessary for the accumulated water from runoff to equal the fresh water volume of the sound on April 15.

Table 7. Concentrations of orthophosphate (PO_4^{-3}), total phosphate ($T\text{-}PO_4^{-3}$), nitrate (NO_3^-), ammonia (NH_4^+, silica (SiO_2), Aluminum (Al^{+3}) and iron [Fe] along with pH, chemical oxygen demand (COD) and conductivity for all of the streams studied during June 1986.

Table 8. Nitrate and ammonia concentrations in fog, rain and streams as observed on Mount Desert Island and in Hubbard Experimental Forest in New Hampshire.

Table 9a and b. Phosphate and sulfate concentrations observed in Somes Sound on April 15 (a) and April 19 (b). Station locations are indicated in Figures 1 and 8 for April 15 and April 19 respectively.

Table 10. Oxygen content of Somes Sound as indicated by Gilmartin (1986). The values are recorded as percent of oxygen saturation.

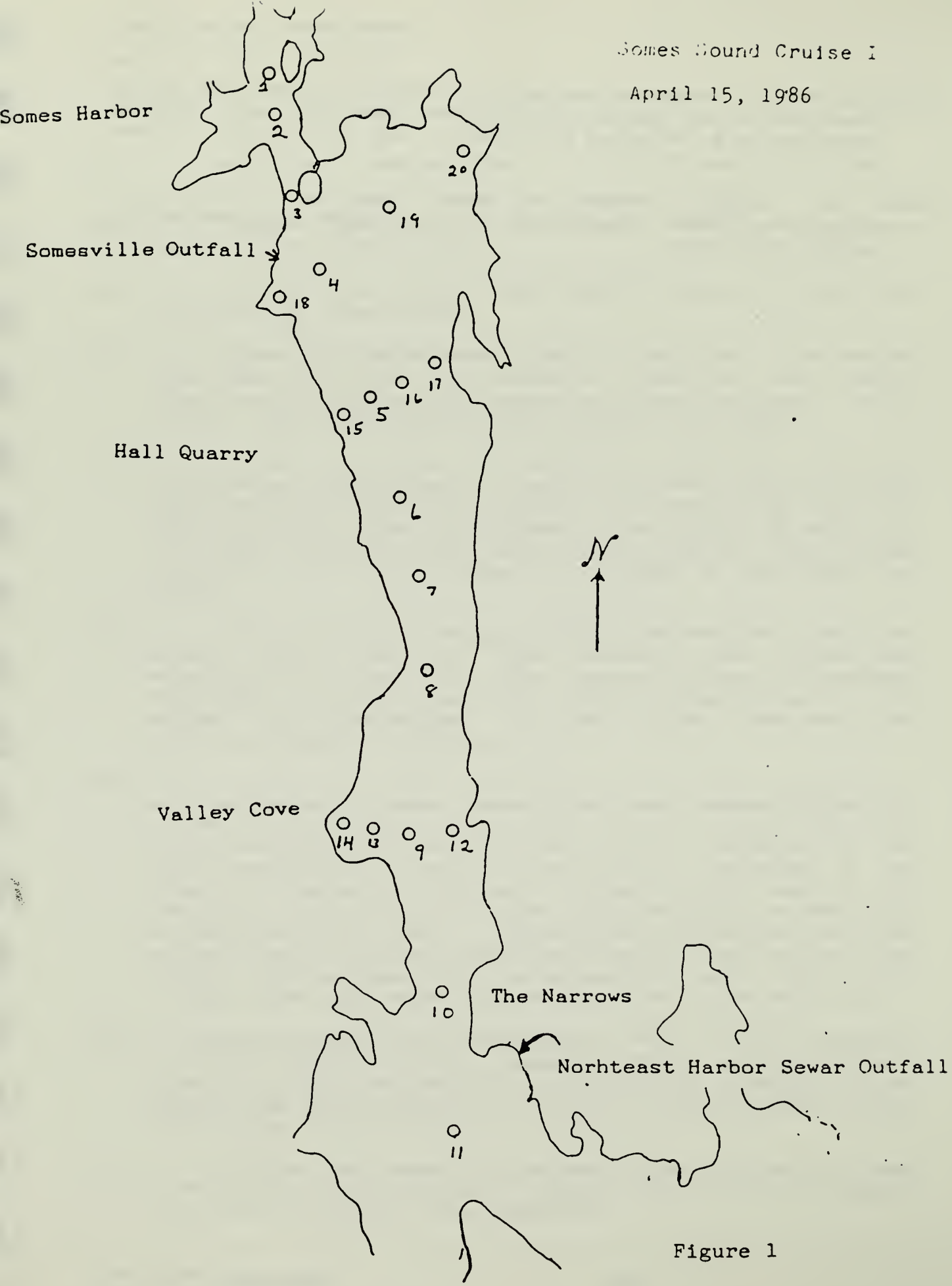

Somes Sound Cruise I
April 15, 1986
Somes Harbor
Somesville Outfall
Hall Quarry
Valley Cove
The Narrows
Norhteast Harbor Sewar Outfall
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
N

Figure 1

Somes Sound Cruise I

April 15, 1986

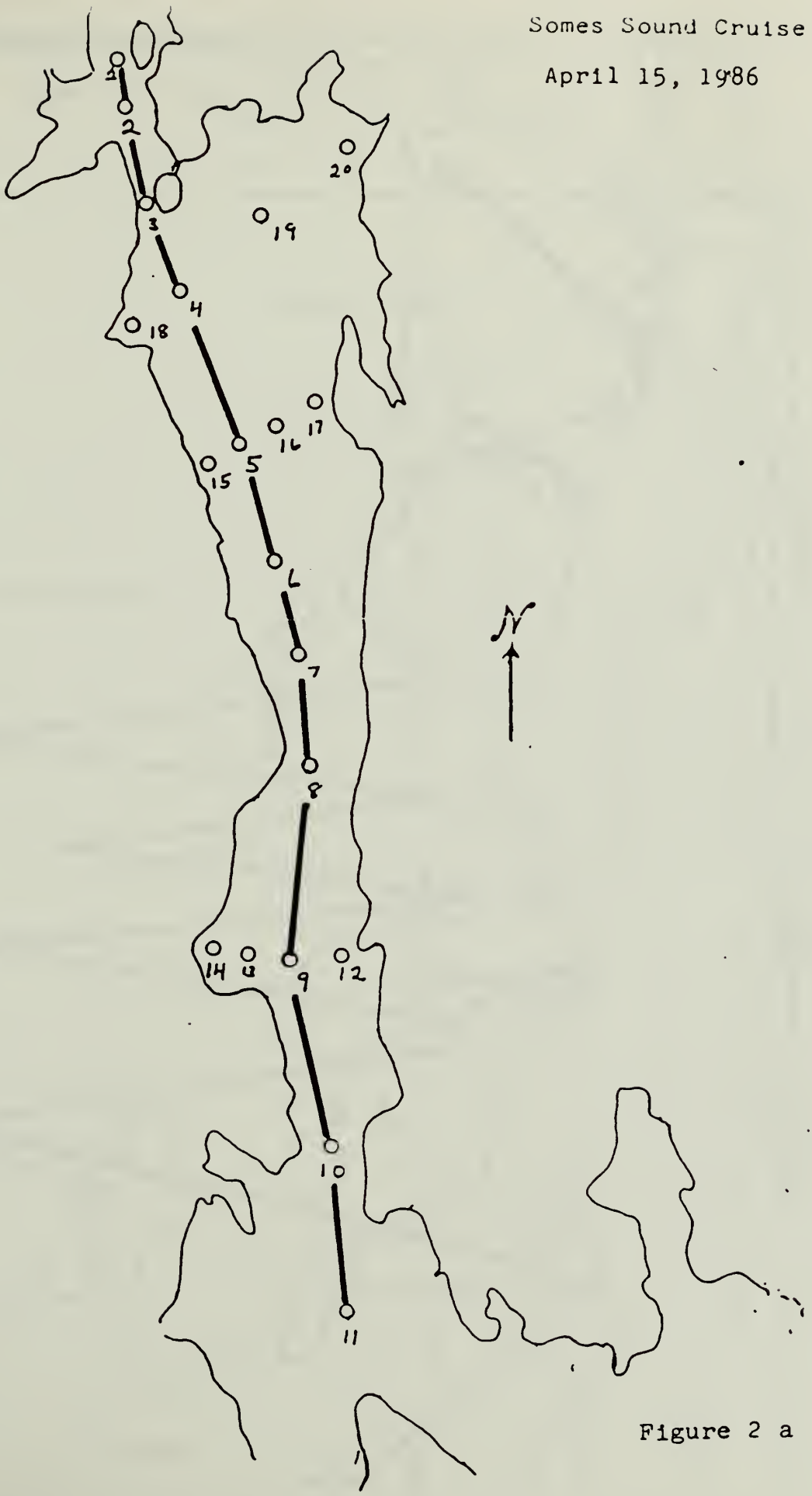


Figure 2 a

Somes Sound Cruise I

April 15, 1986

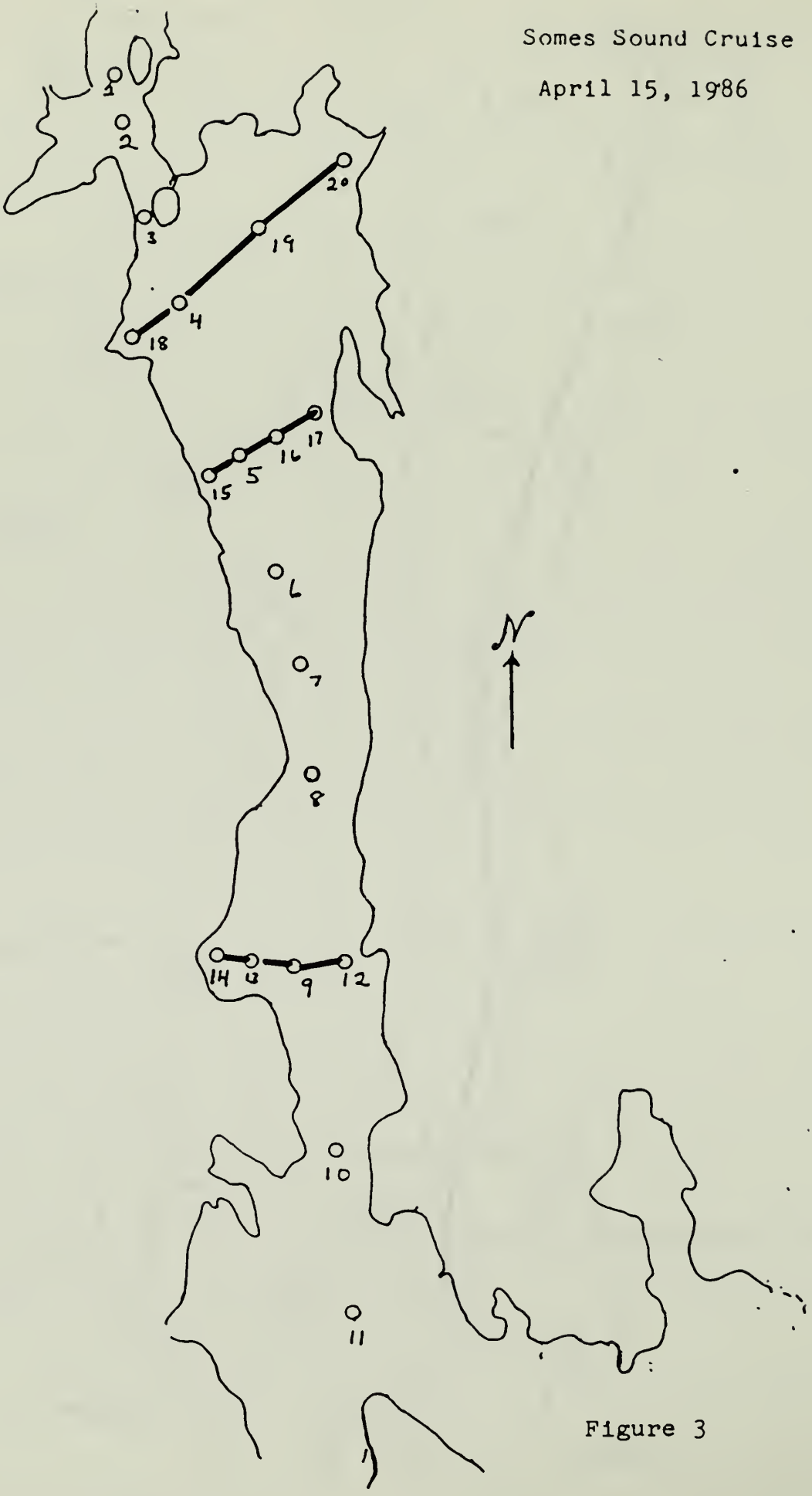
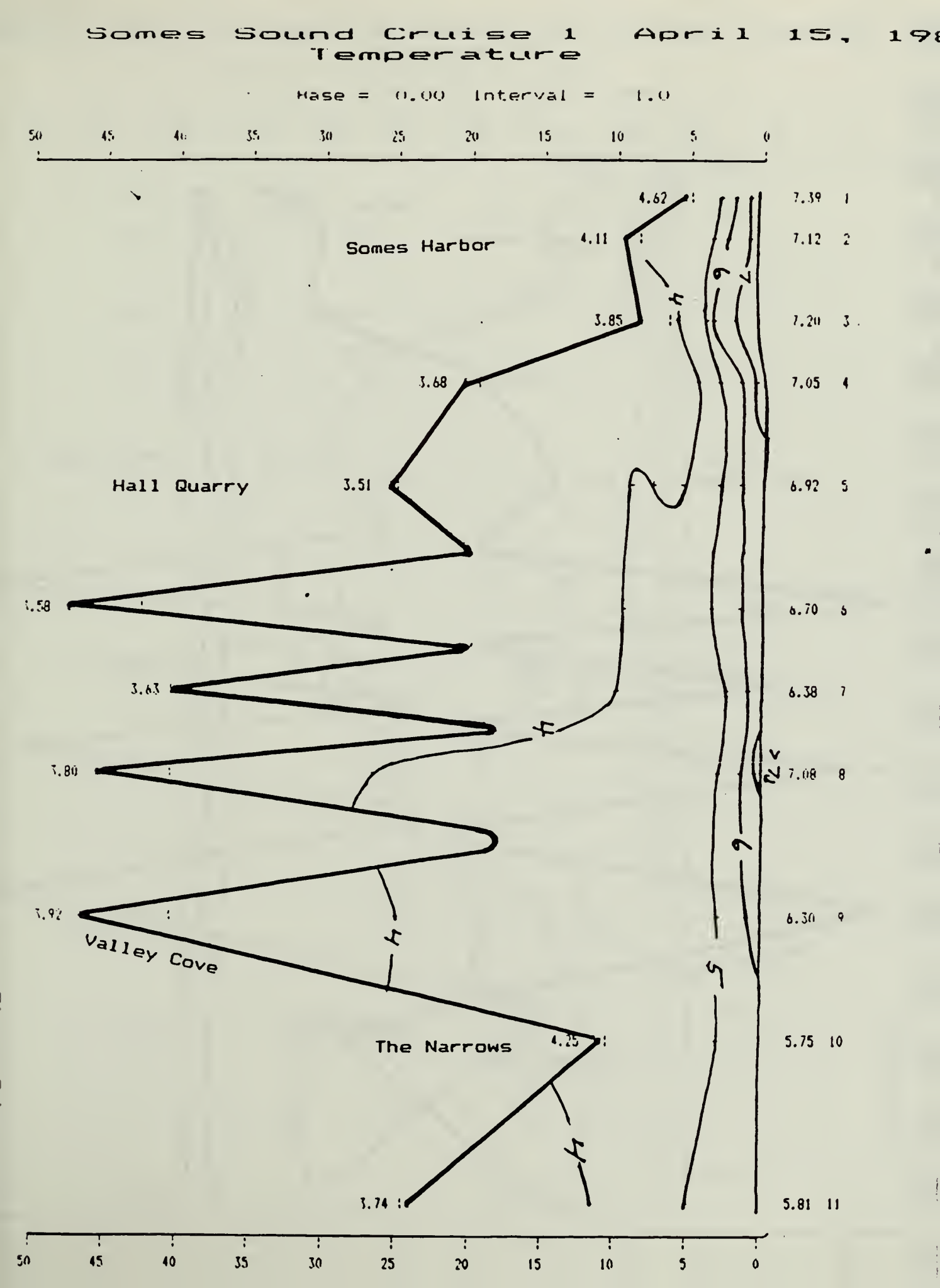


Figure 3


Somes Sound Cruise 1 April 15, 198
Temperature
Base = 0.00 Interval = 1.0
50 45 40 35 30 25 20 15 10 5 0
Somes Harbor
Hall Quarry
Valley Cove
The Narrows
4.62
4.11
3.85
3.68
3.51
3.58
3.63
3.80
3.92
4.25
3.74
7.39 1
7.12 2
7.20 3
7.05 4
6.92 5
6.70 6
6.38 7
7.08 8
6.30 9
5.75 10
5.81 11

Somes Sound Cruise 1 April 15, 1986
Sigma-t

Base = 22.00 Interval = 0.5

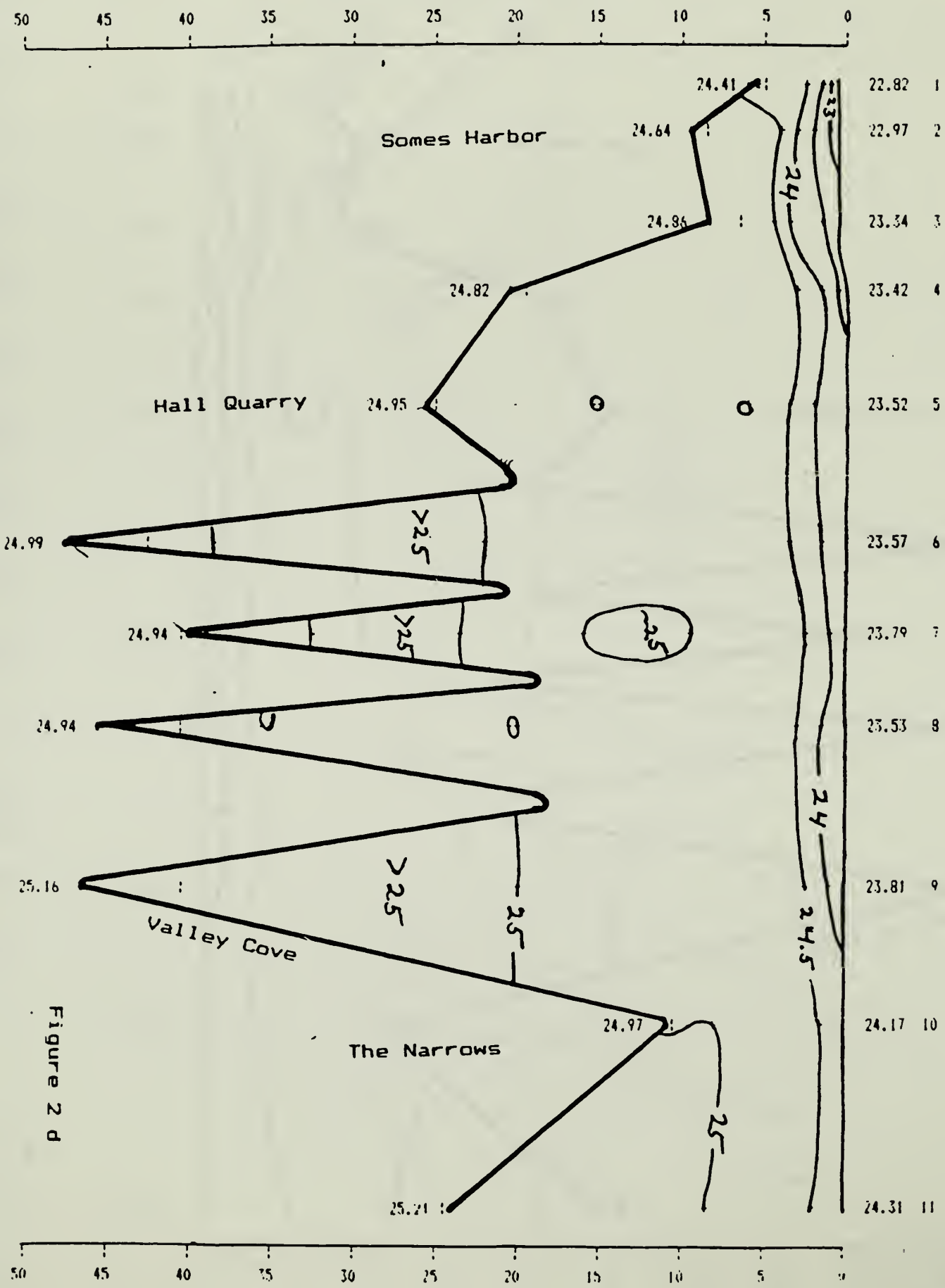
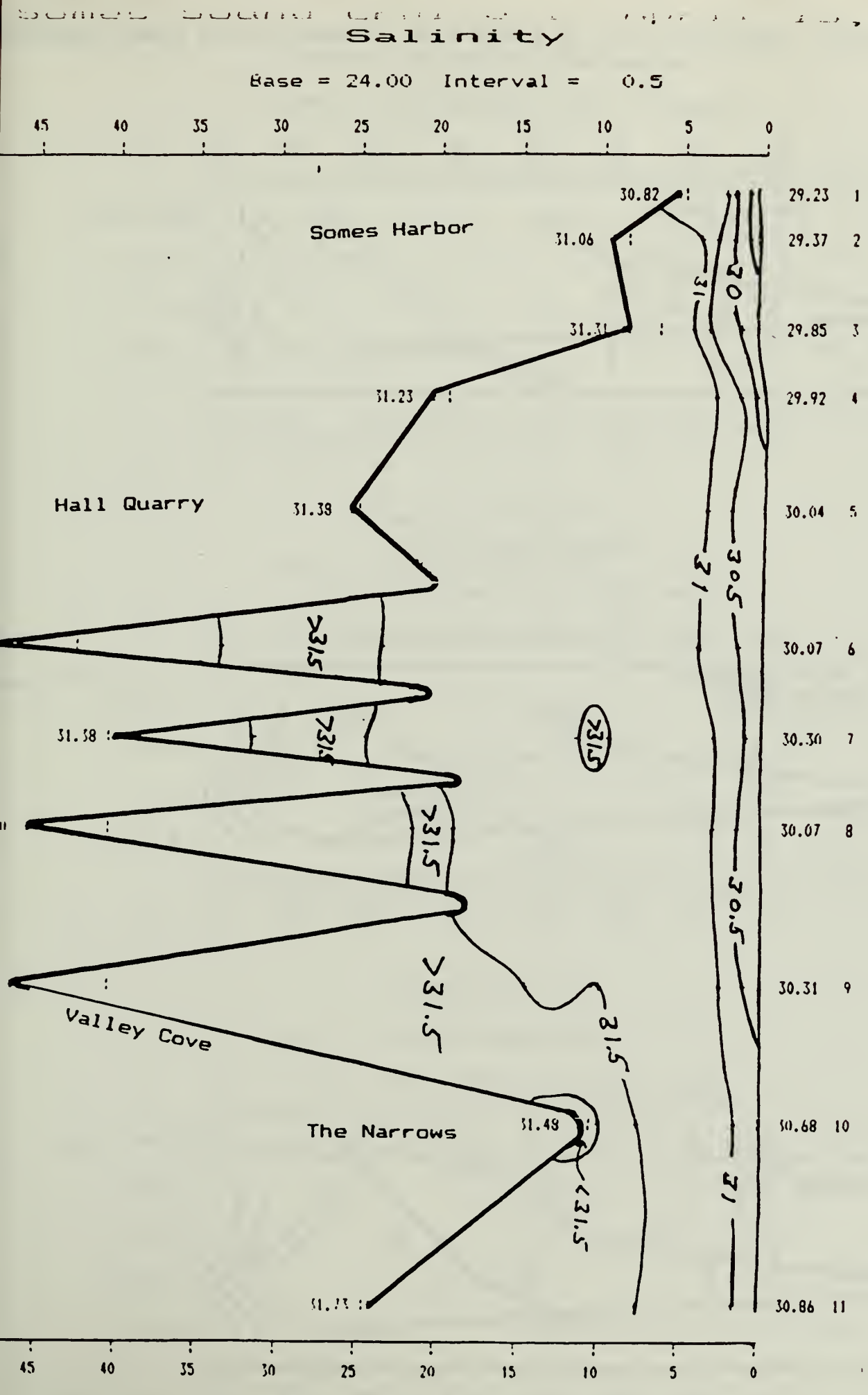


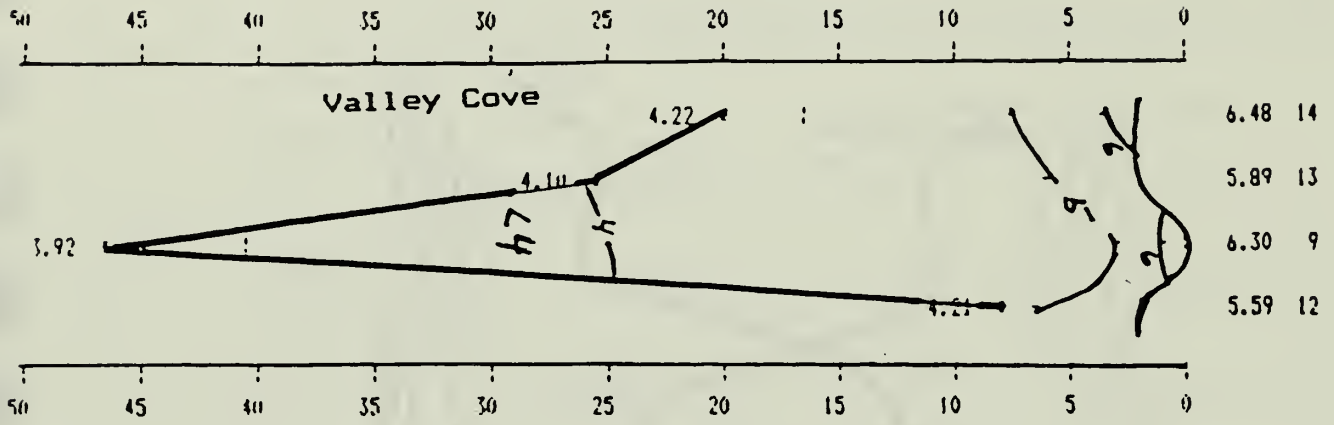
Figure 2 d


Salinity
Base = 24.00 Interval = 0.5
45 40 35 30 25 20 15 10 5 0
Somes Harbor
Hall Quarry
Valley Cove
The Narrows
30.82
31.06
31.31
31.23
31.38
31.38
31.48
31.73
29.23 1
29.37 2
29.85 3
29.92 4
30.04 5
30.07 6
30.30 7
30.07 8
30.31 9
30.68 10
30.86 11
<31.5
<31.5
<31.5
<31.5
<31.5
<31.5
31
30
30.5
31
30.5
31
45 40 35 30 25 20 15 10 5 0

Somes Sound Cruise 1 April 15, 1986

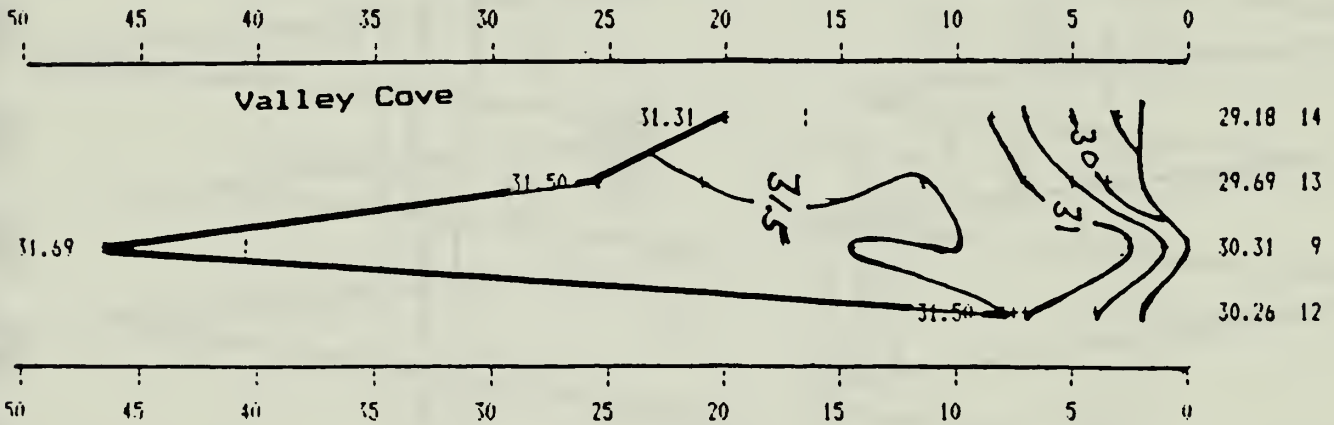
Temperature

Base = 0.00 Interval = 1.0



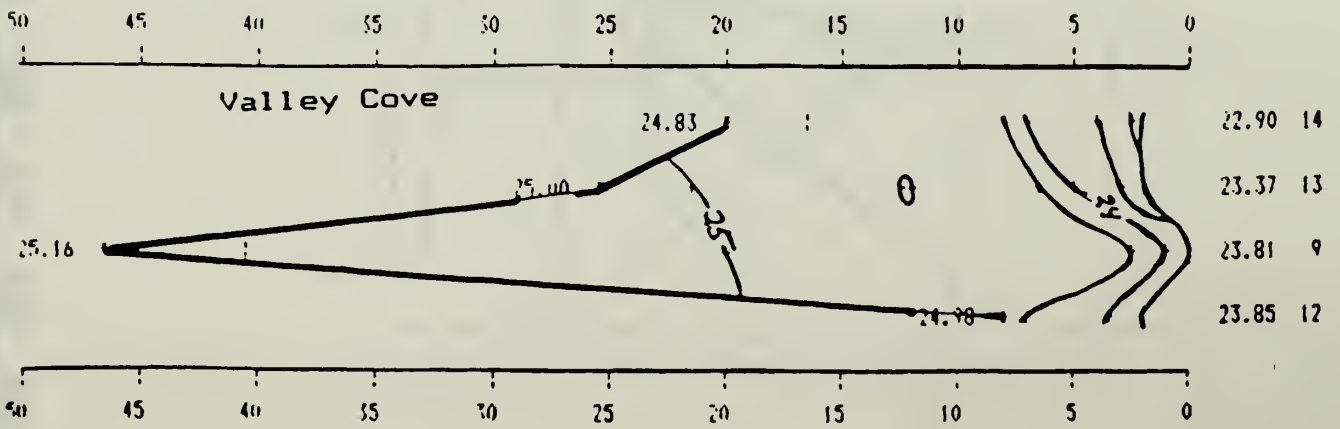
Salinity

Base = 24.00 Interval = 0.5



Sigma-t

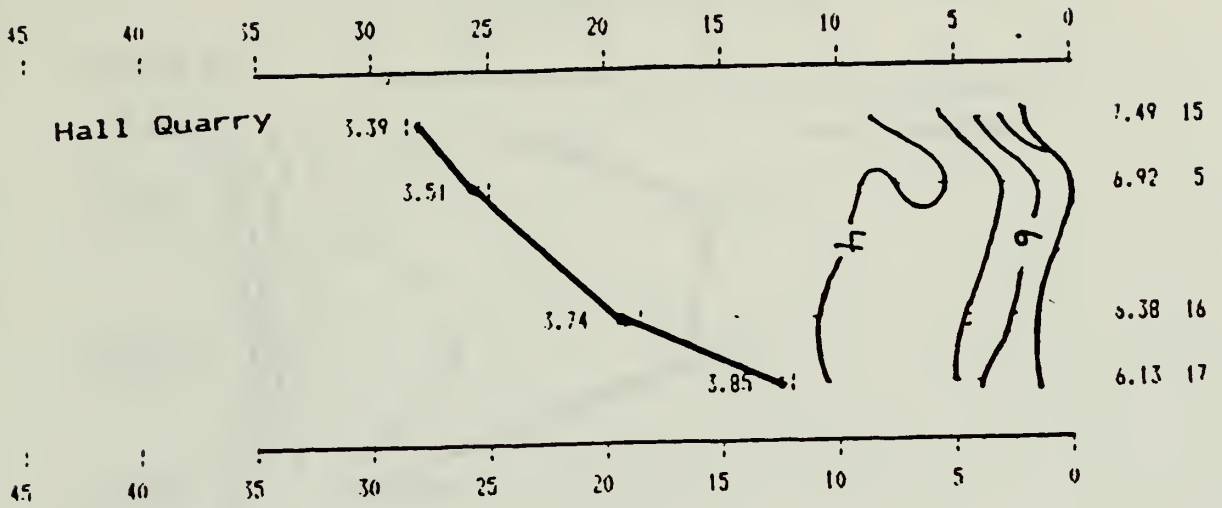
Base = 22.00 Interval = 0.5



Somes Sound Cruise 1 April 15, 1986

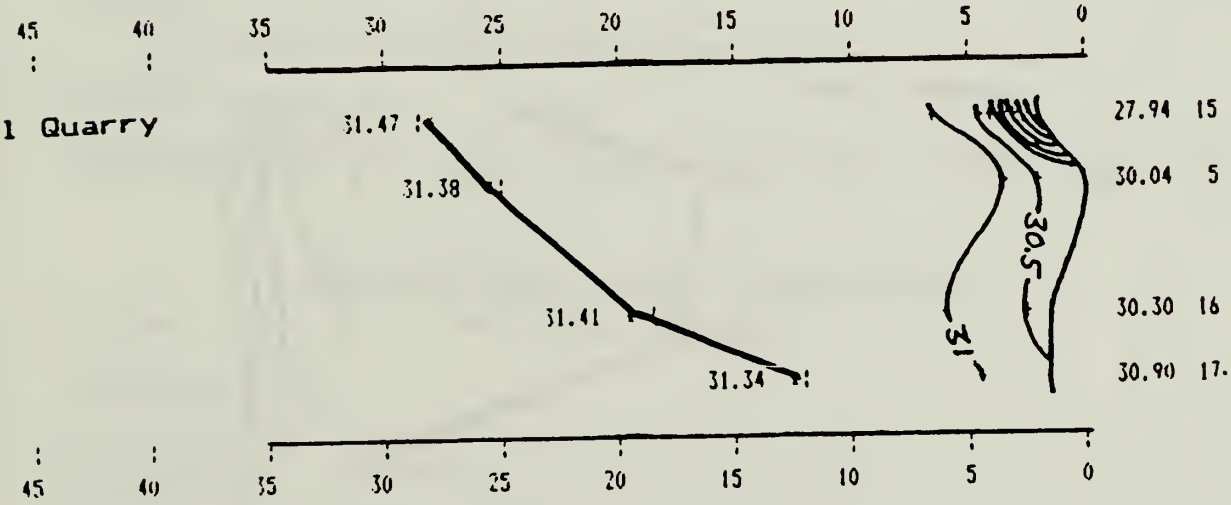
Temperature

Base = 0.00 Interval = 1.0



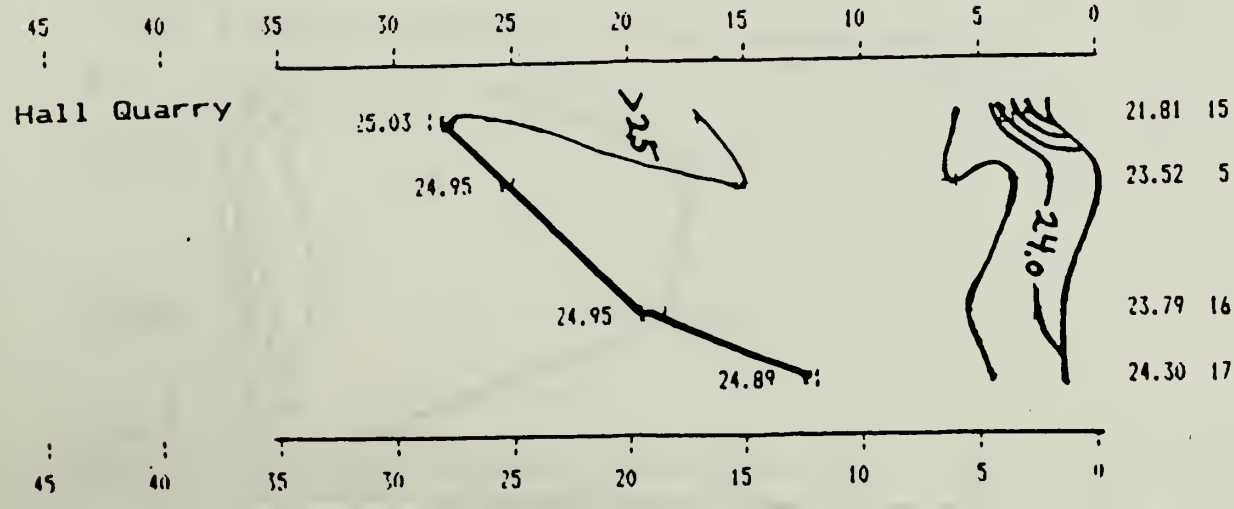
Salinity

Base = 24.00 Interval = 0.5



Sigma-t

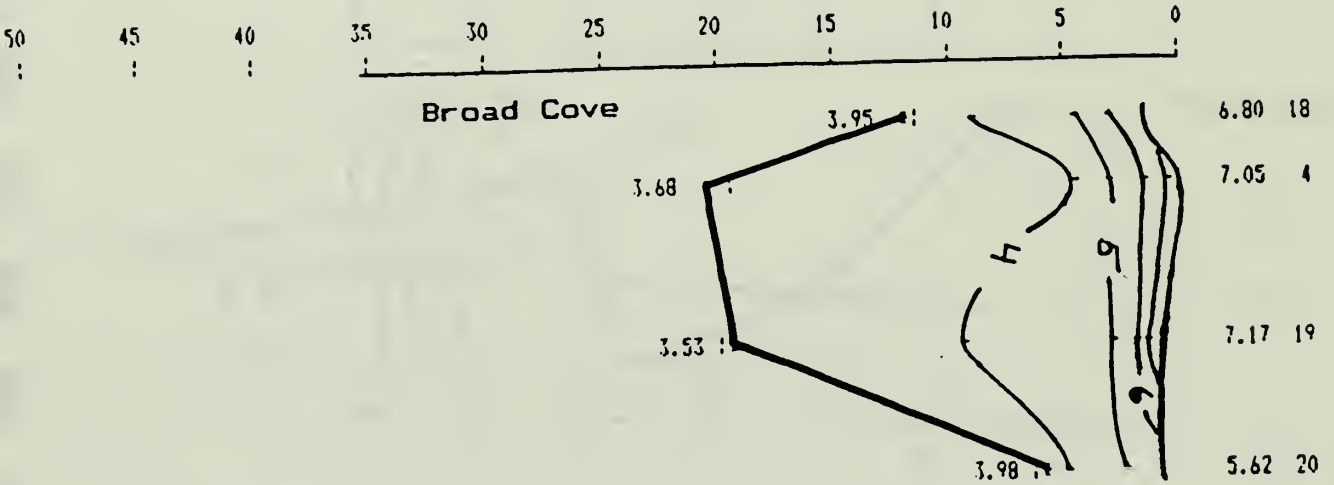
Base = 22.00 Interval = 0.5



Somes Sound Cruise 1 April 15, 1986

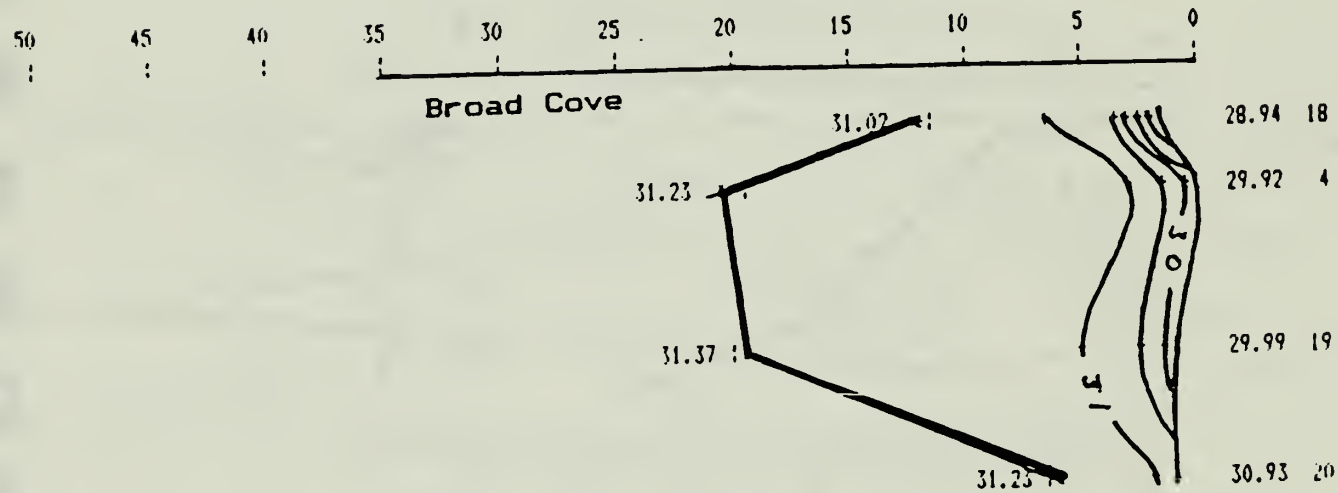
Temperature

Base = 0.00 Interval = 1.0



Salinity

Base = 24.00 Interval = 0.5



Sigma-t

Base = 22.00 Interval = 0.5

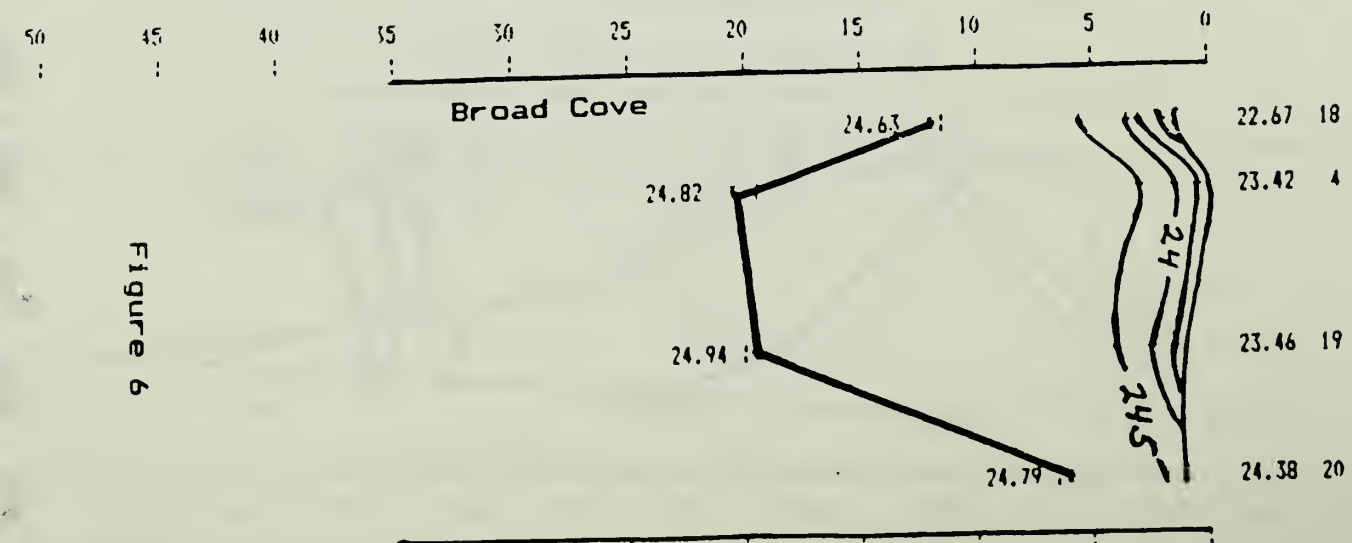
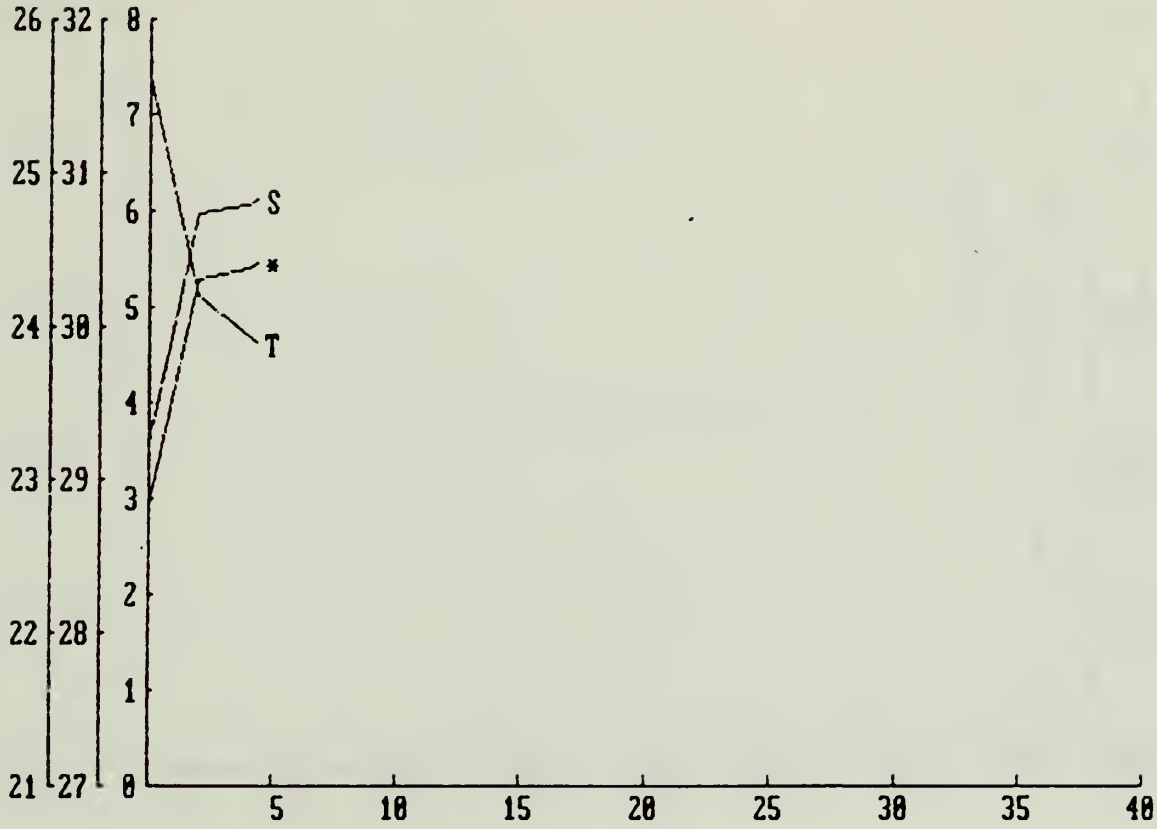


Figure 6

Somes Sound Cruise 1 April 15, 1986 Station # 1
44 21.8 N 68 19.7 W



Somes Sound Cruise 1 April 15, 1986 Station # 2
44 21.7 N 68 19.6 W

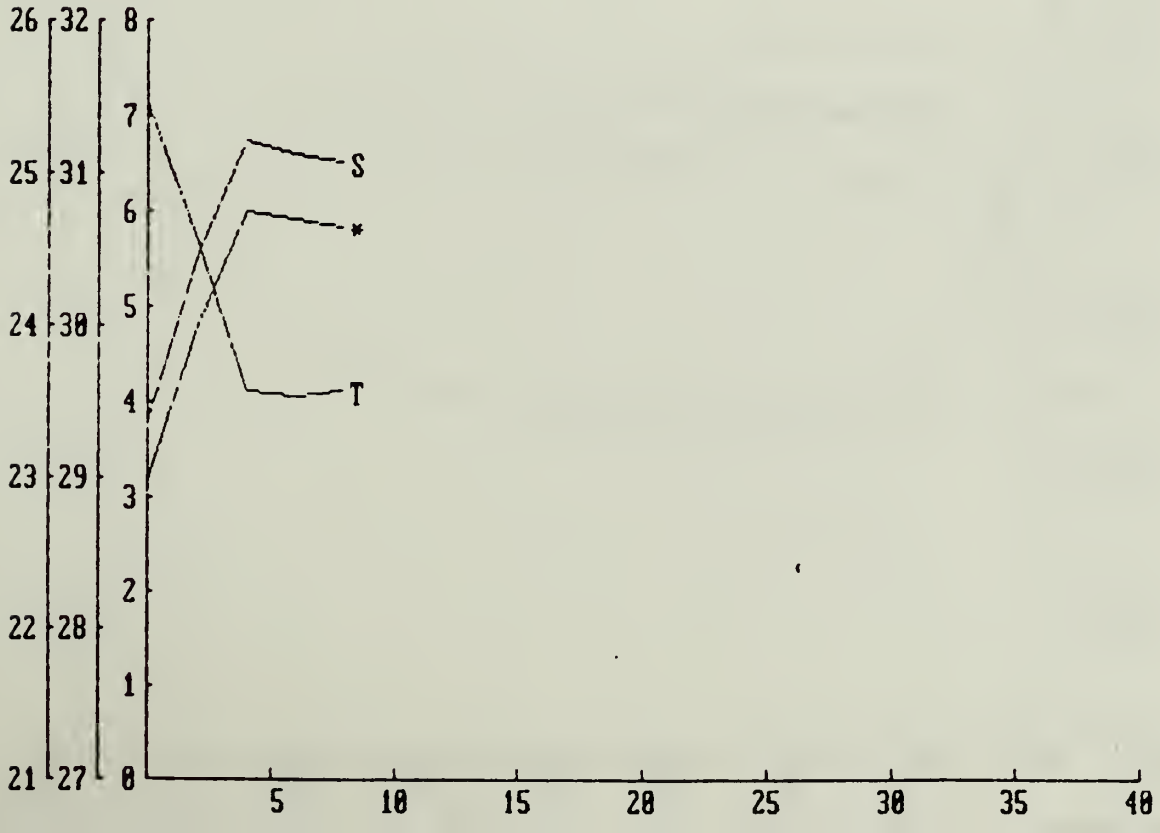
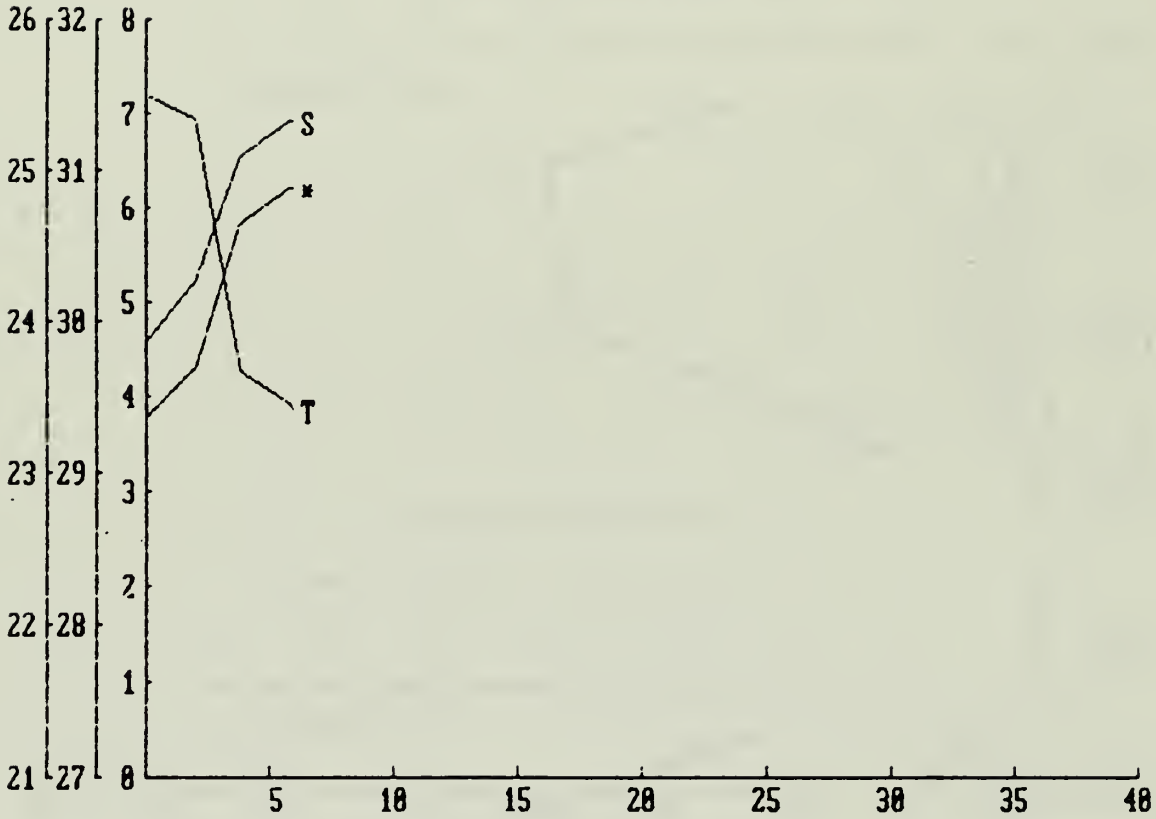


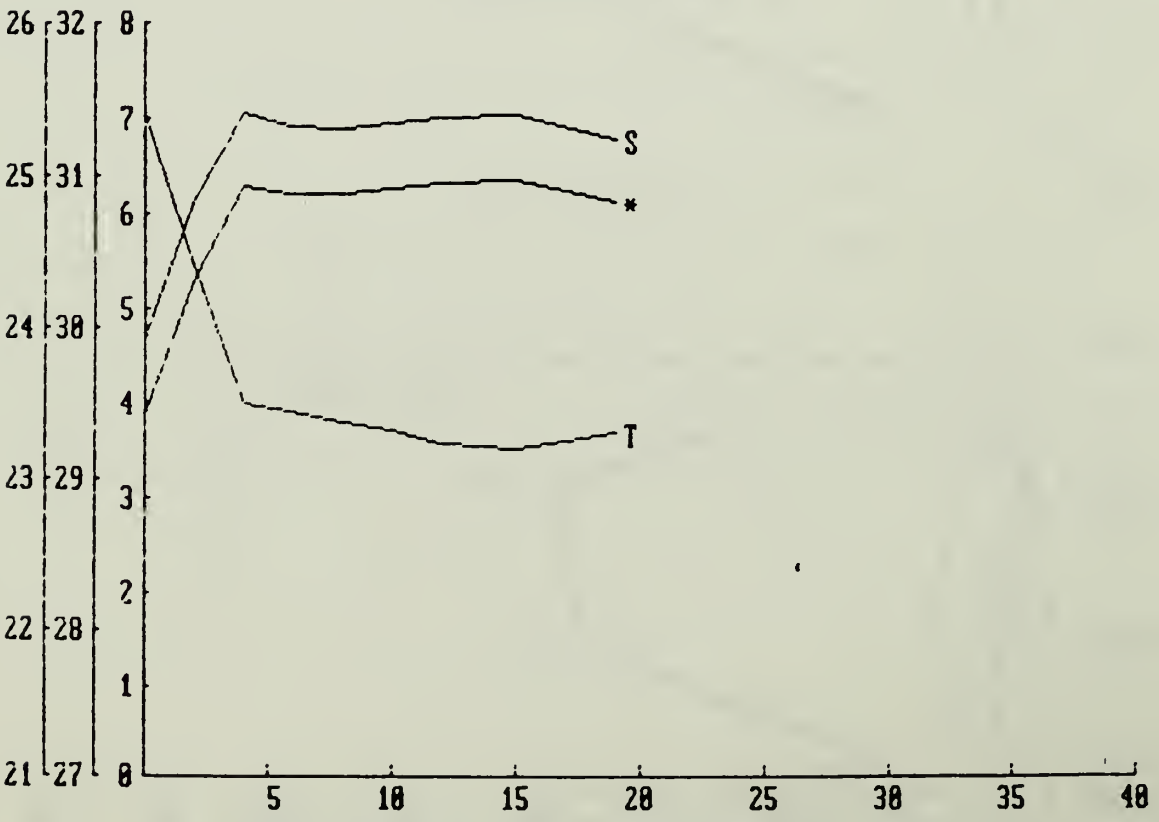
Figure 7

Figure 7 (cont.)

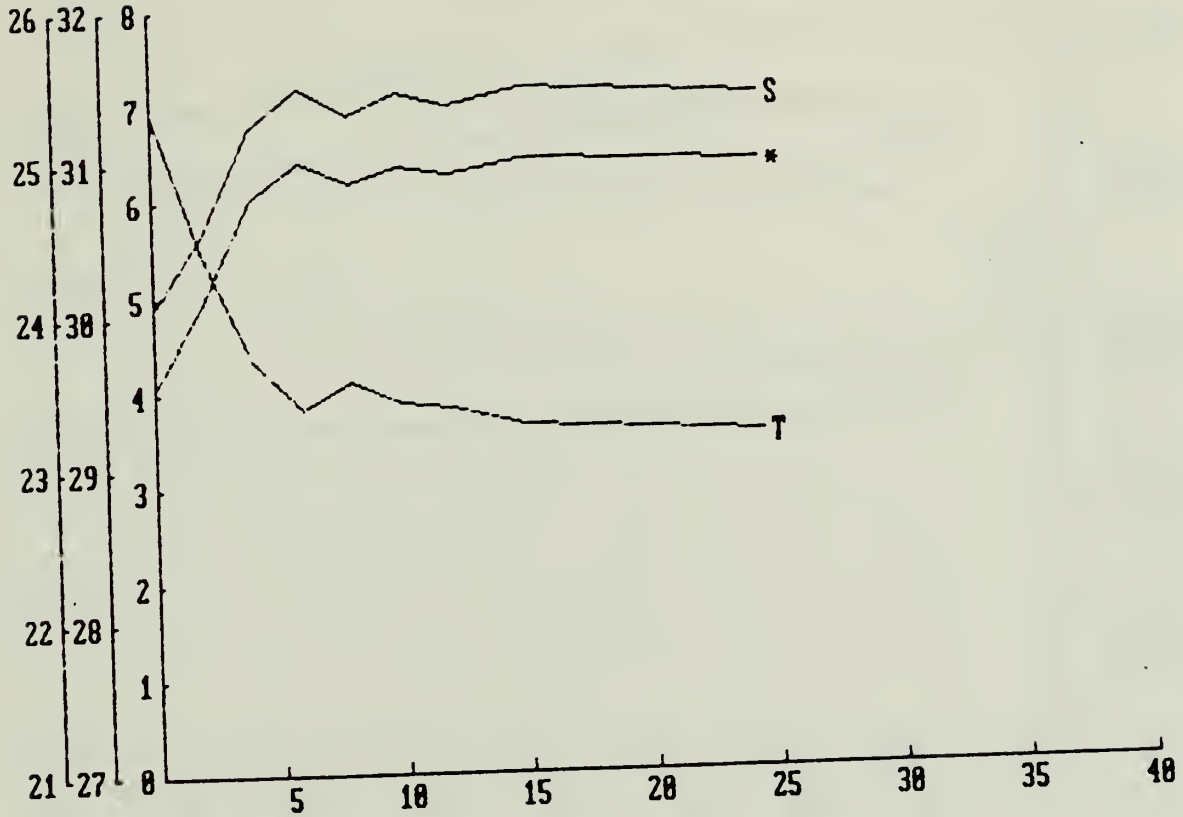
Somes Sound Cruise 1 April 15, 1986 Station # 3
44 21.3 N 68 19.5 W



Somes Sound Cruise 1 April 15, 1986 Station # 4
44 21.8 N 68 19.4 W



Somes Sound Cruise 1 April 15, 1986 Station # 5
44 28.4 N 68 19.5 W



Somes Sound Cruise 1 April 15, 1986 Station # 6
44 28.8 N 68 18.9 W

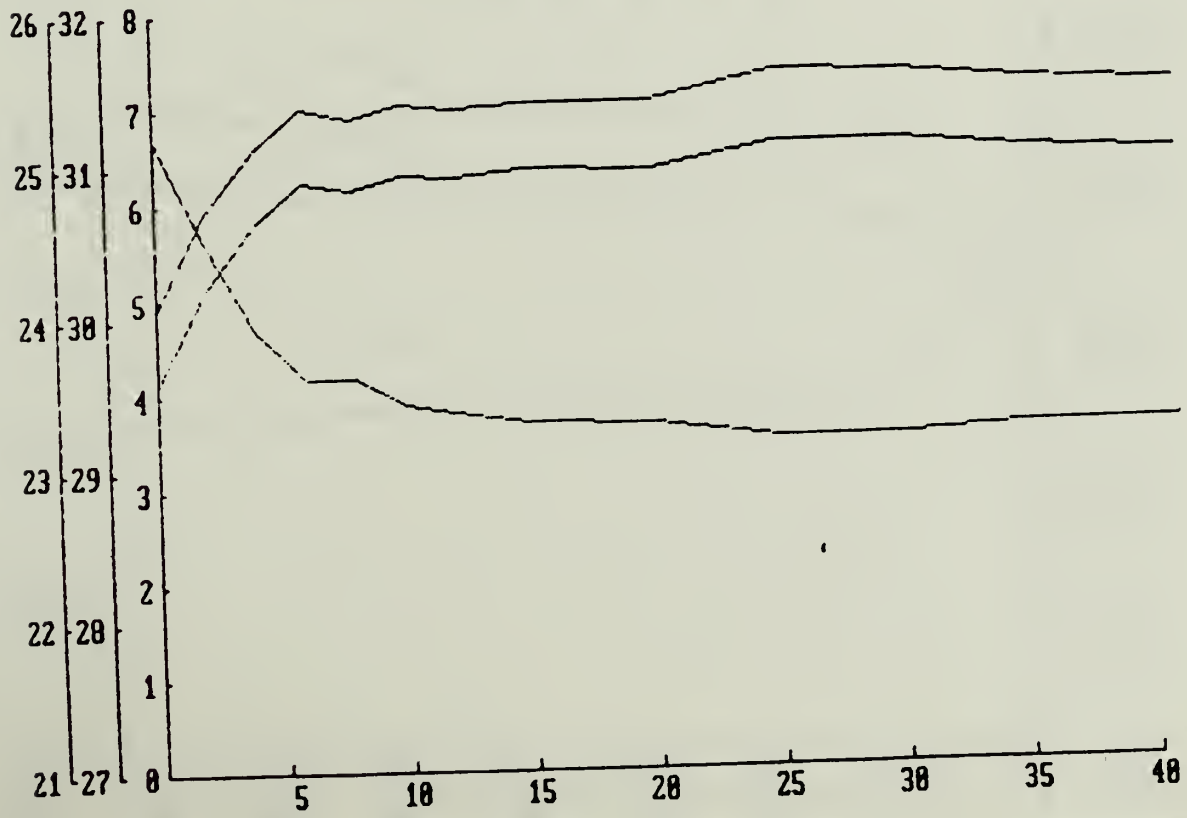


Figure 7 (cont.)

Figure 7 (cont.)

Somes Sound Cruise 1 April 15, 1986 Station # 7
44 19.7 N 68 18.8 W

Somes Sound Cruise 1 April 15, 1986 Station # 8
44 19.3 N 68 18.8 W

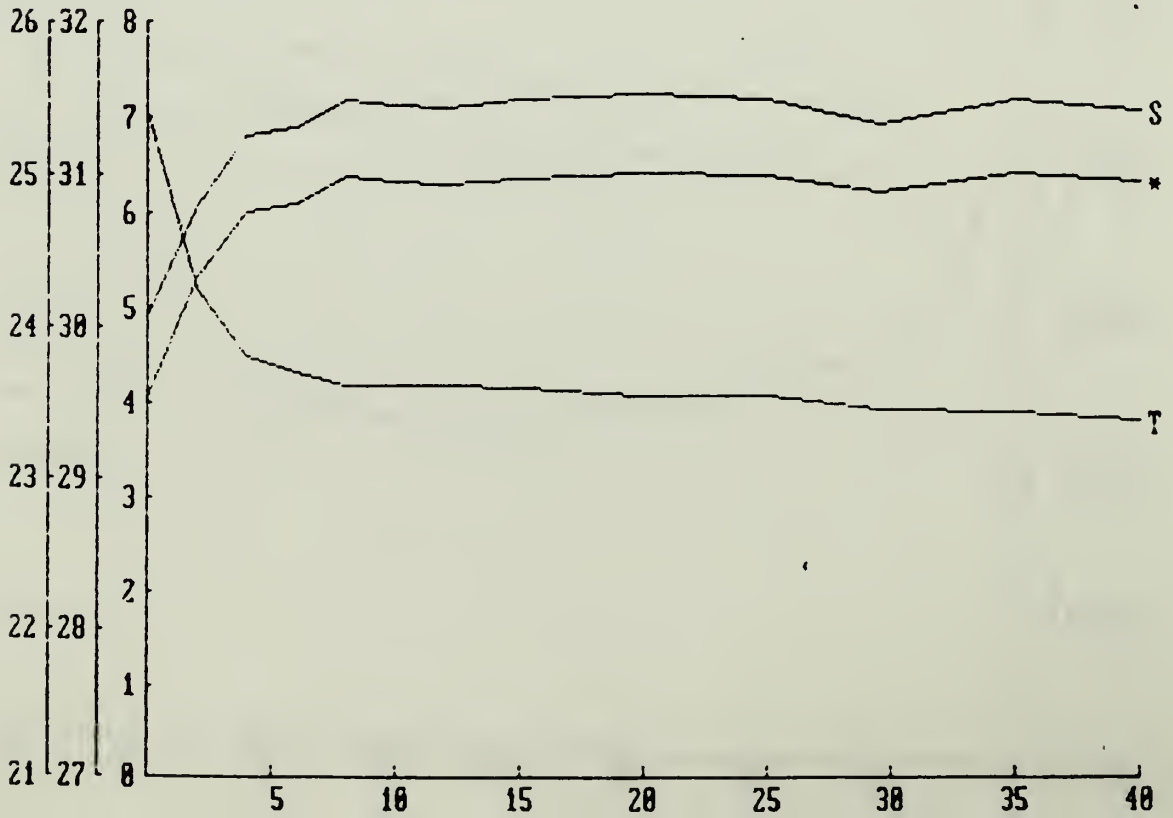
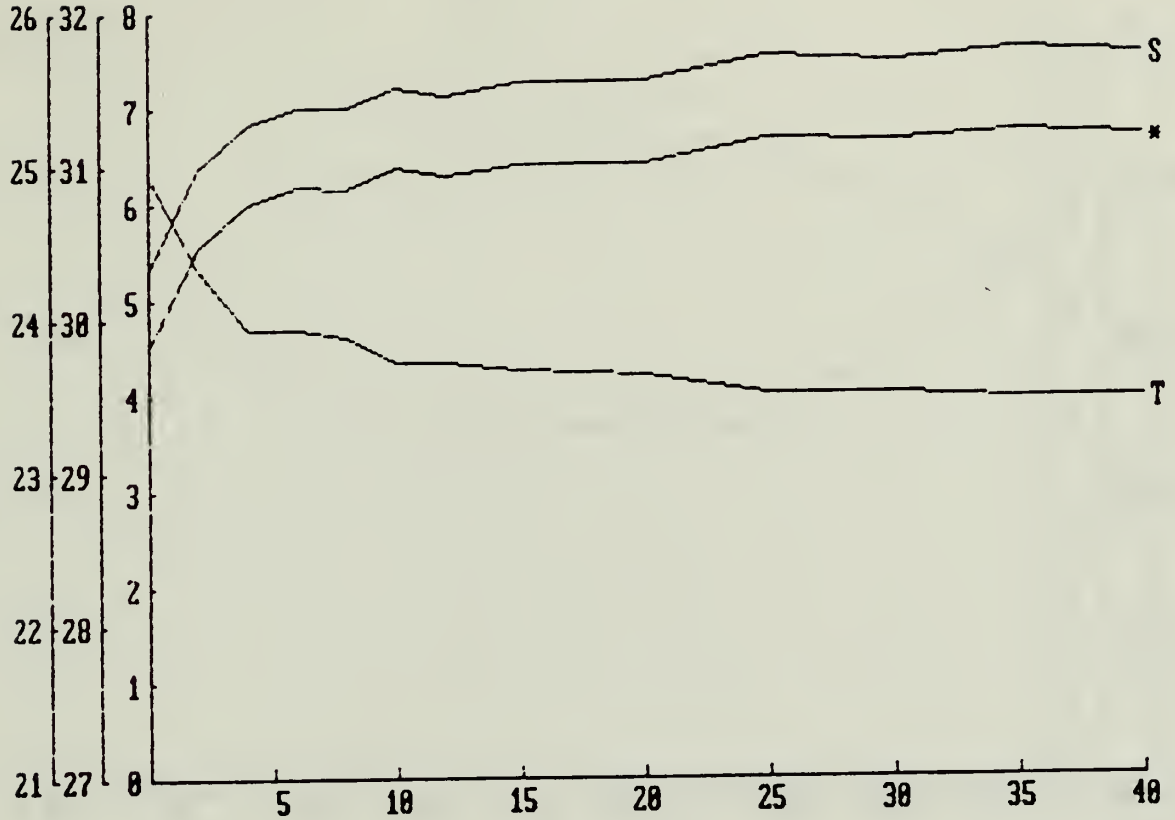


Figure 7 (cont.)

Somes Sound Cruise 1 April 15, 1986 Station # 9
44 18.6 N 68 18.8 W



Somes Sound Cruise 1 April 15, 1986 Station # 10
44 18.1 N 68 18.6 W

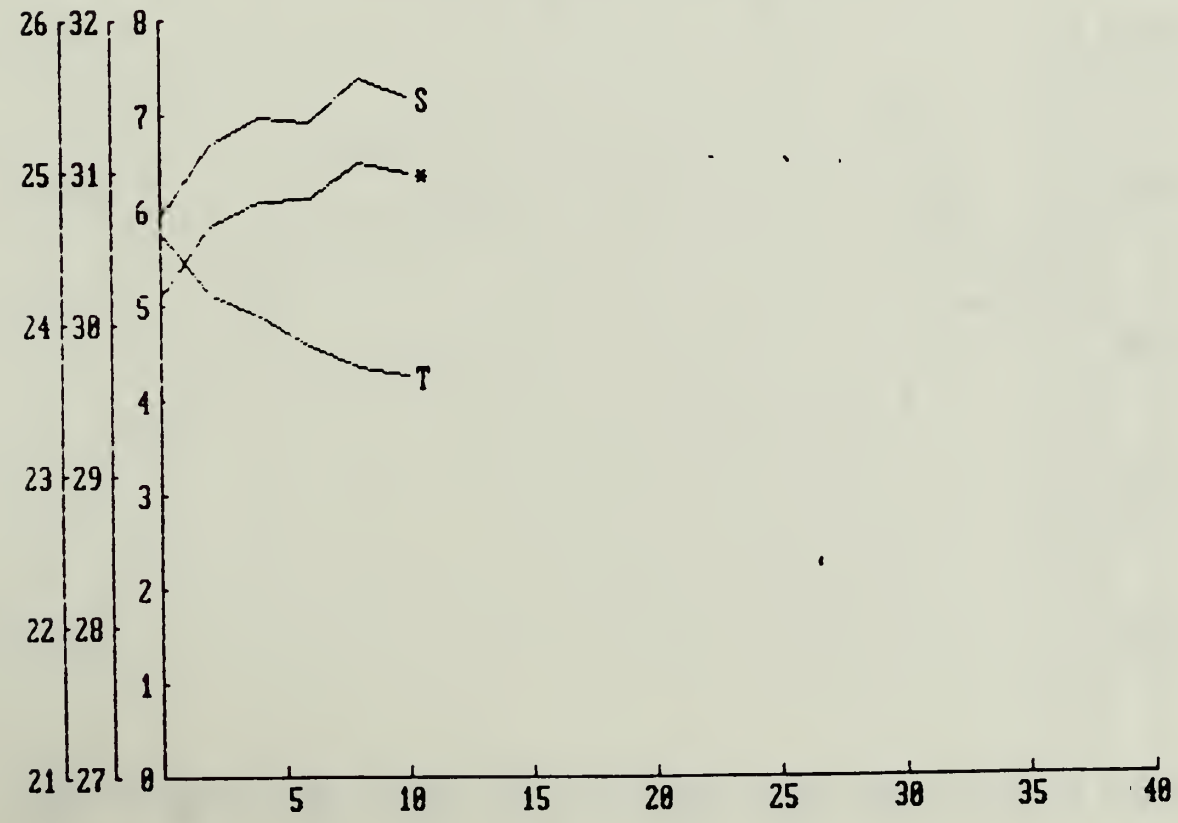
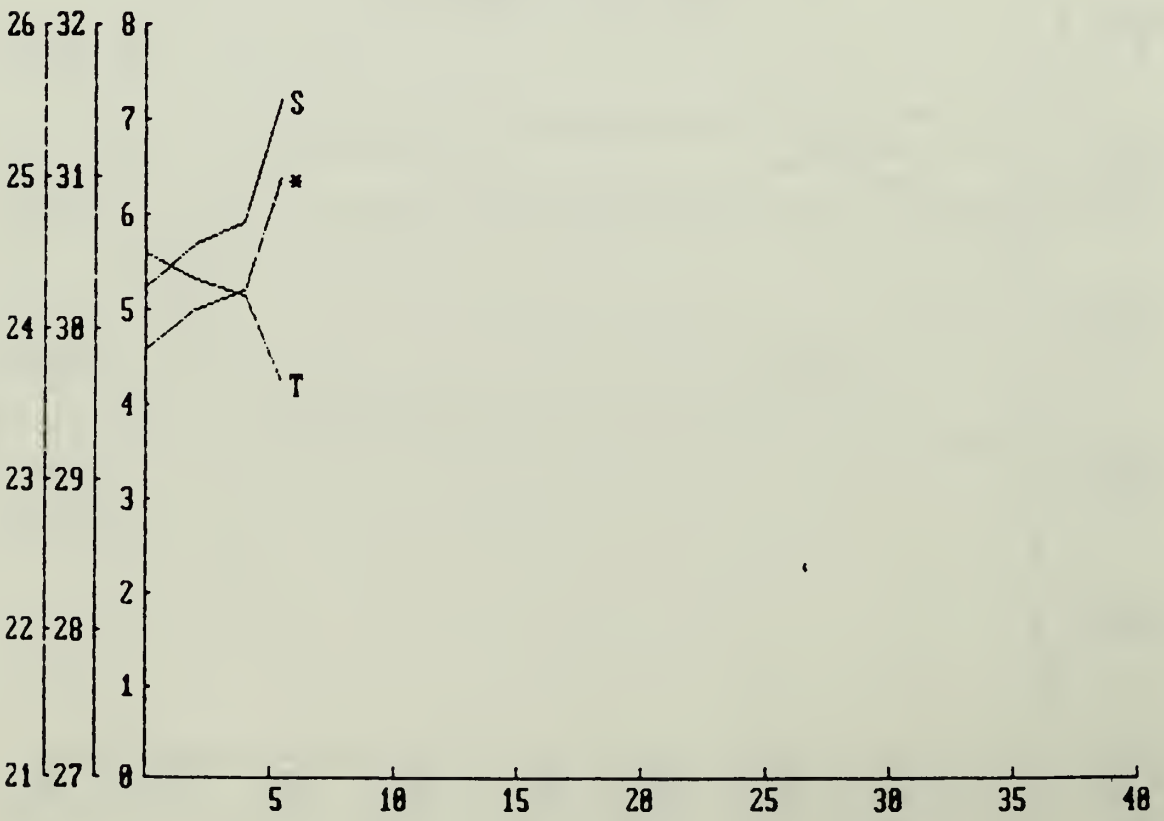


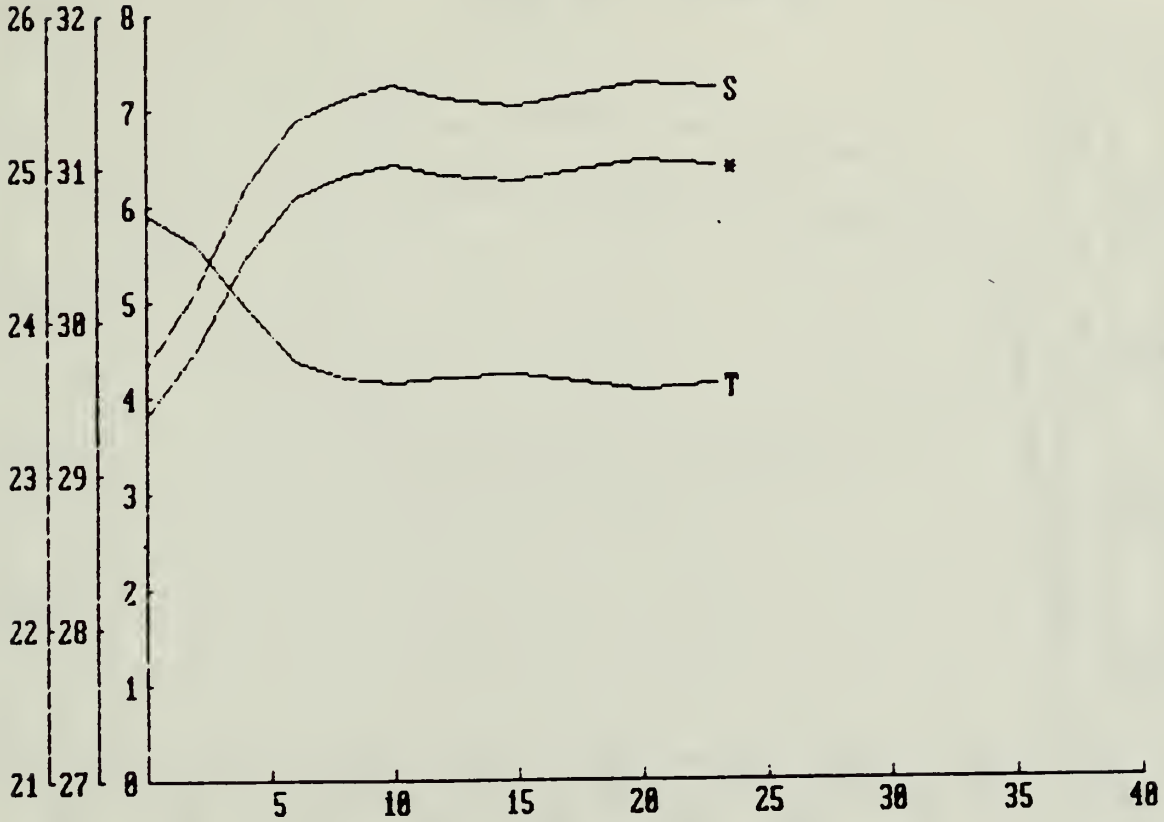
Figure 7 (cont.)

Somes Sound Cruise 1 April 15, 1986 Station # 11
44 17.3 N 68 18.5 W

Somes Sound Cruise 1 April 15, 1986 Station # 12
44 18.6 N 68 18.6 W



Somes Sound Cruise 1 April 15, 1986 Station # 13
44 18.6 N 68 19.0 W



Somes Sound Cruise 1 April 15, 1986 Station # 14
44 18.6 N 68 19.2 W

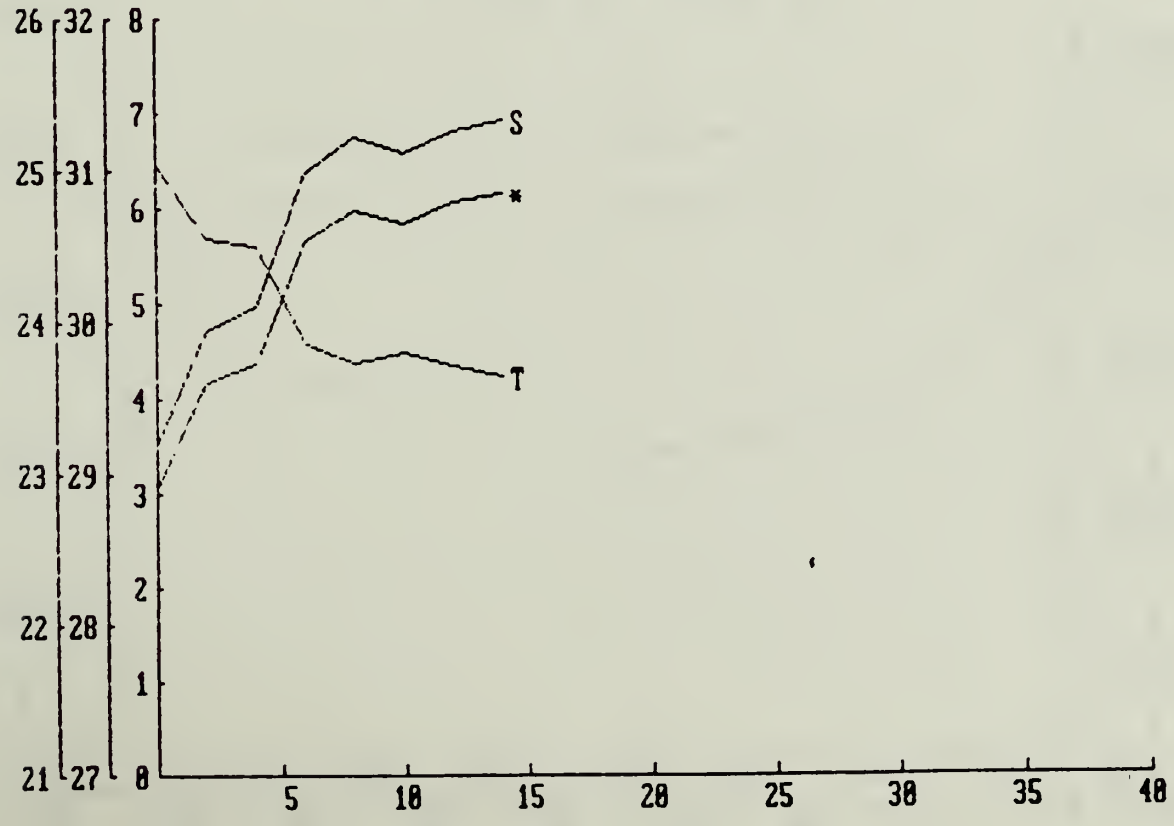


Figure 7 (cont.)

Somes Sound Cruise 1 April 15, 1986 Station # 15
44 20.4 N 68 19.3 W

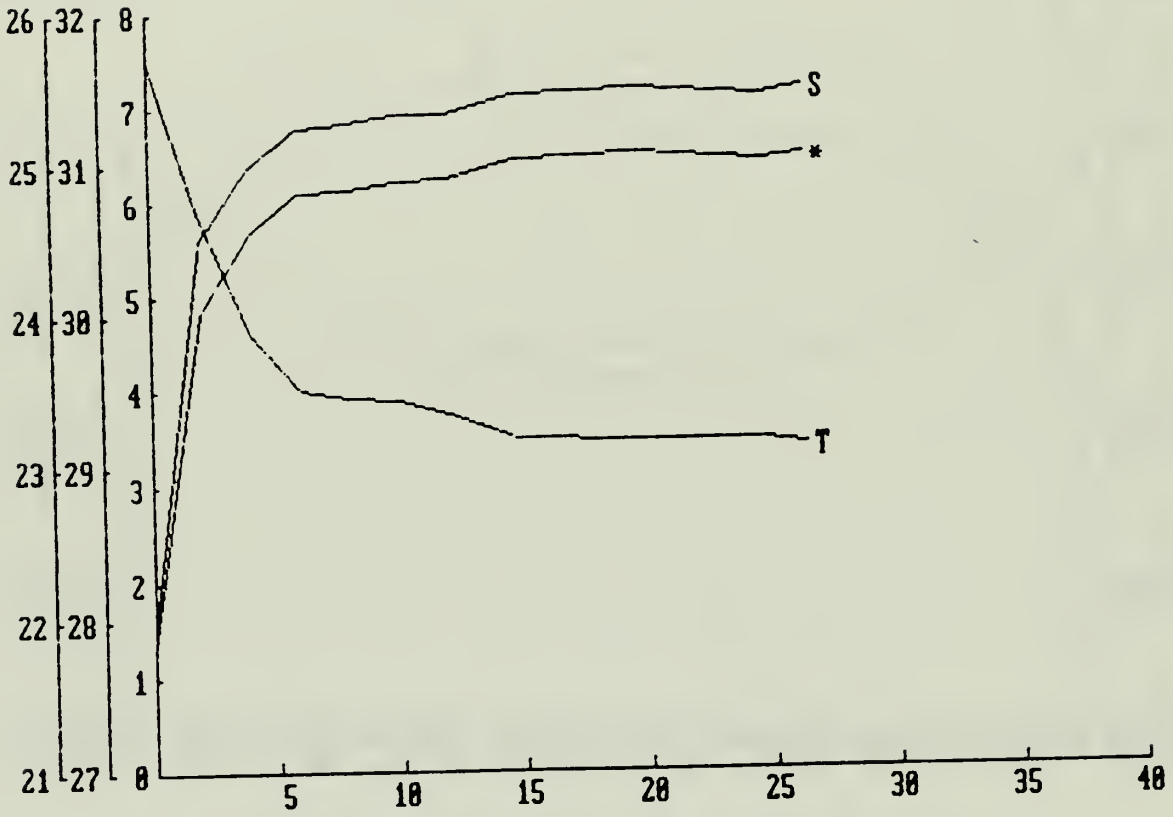
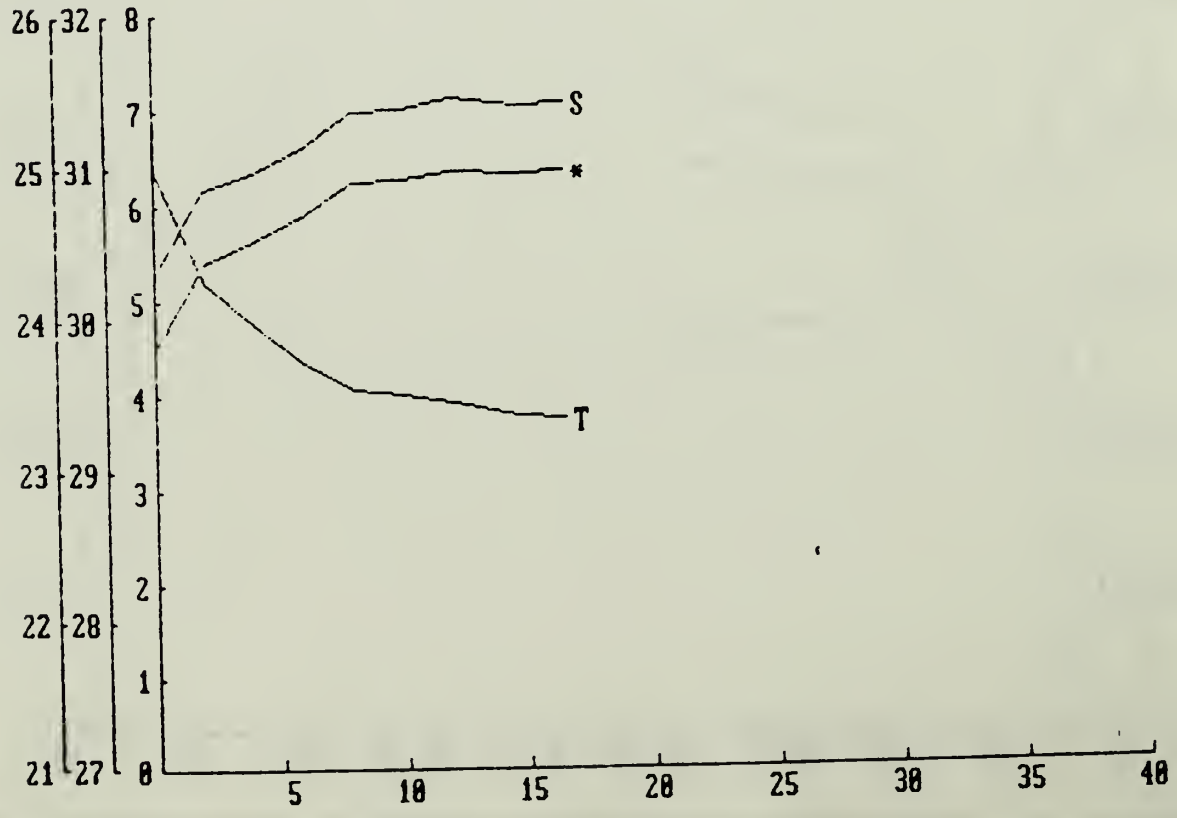
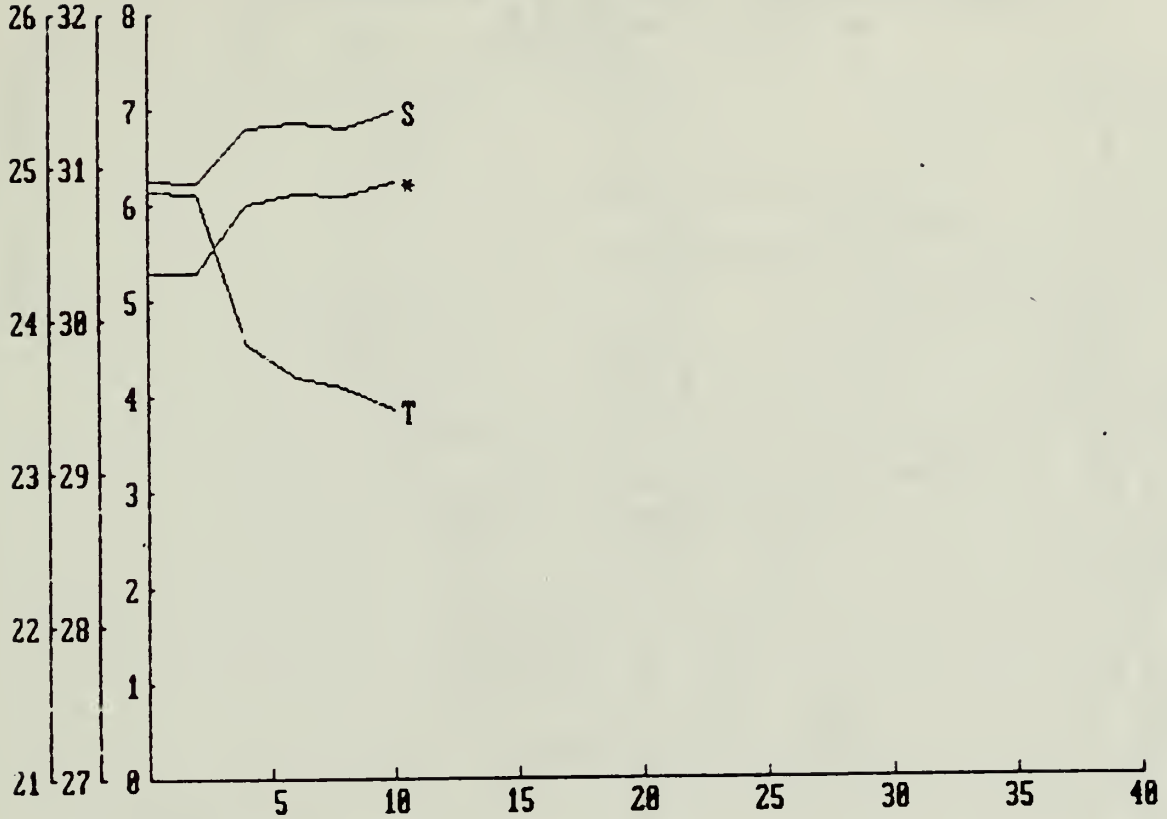


Figure 7 (cont.)

Somes Sound Cruise 1 April 15, 1986 Station # 16
44 20.5 N 68 18.9 W



Somes Sound Cruise 1 April 15, 1986 Station # 17
44 20.6 N 68 18.8 W



Somes Sound Cruise 1 April 15, 1986 Station # 18
44 20.8 N 68 19.6 W

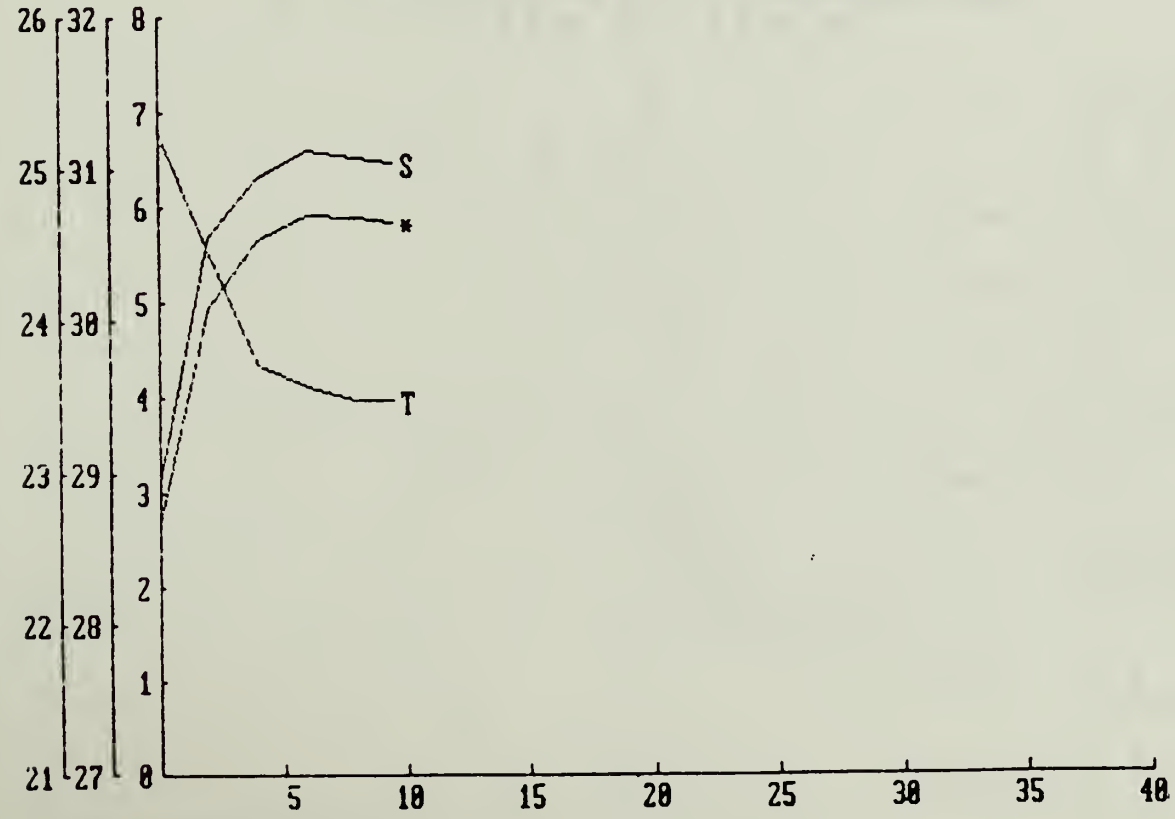


Figure 7 (cont.)

Somes Sound Cruise 1 April 15, 1986 Station # 19
44 21.3 N 68 19.8 W

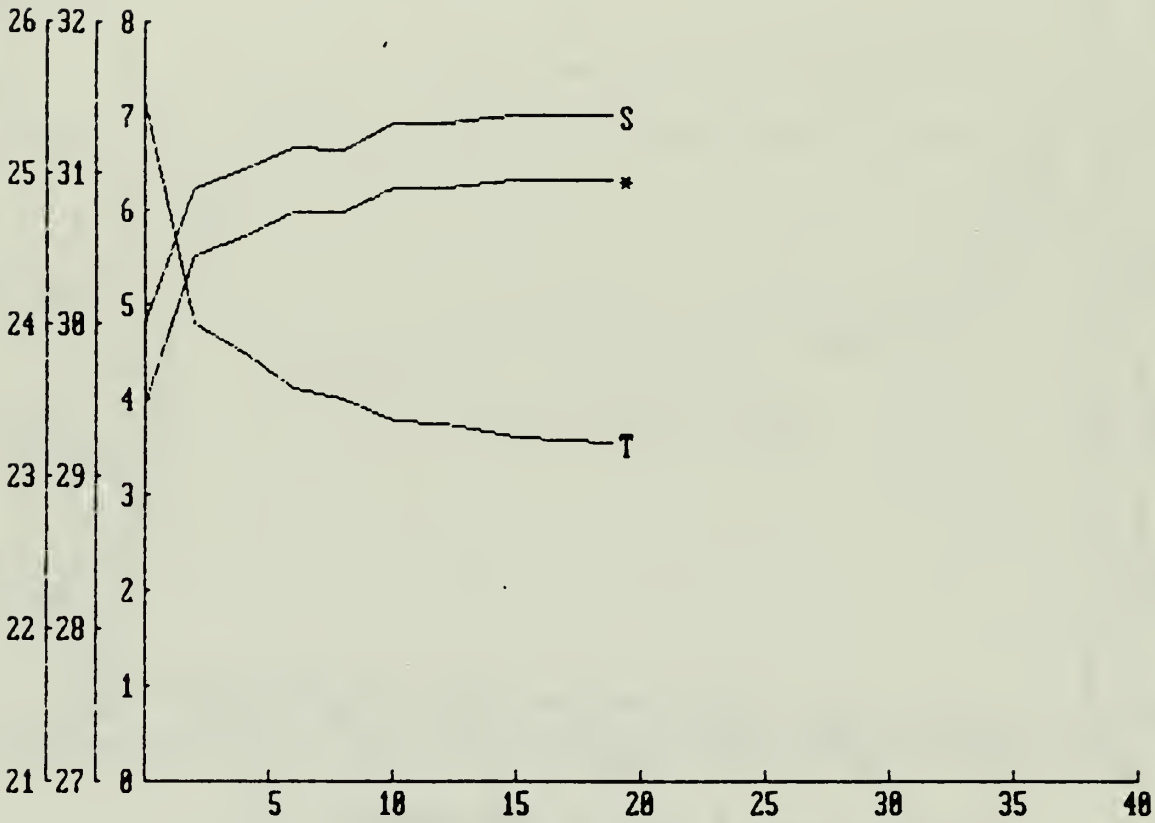
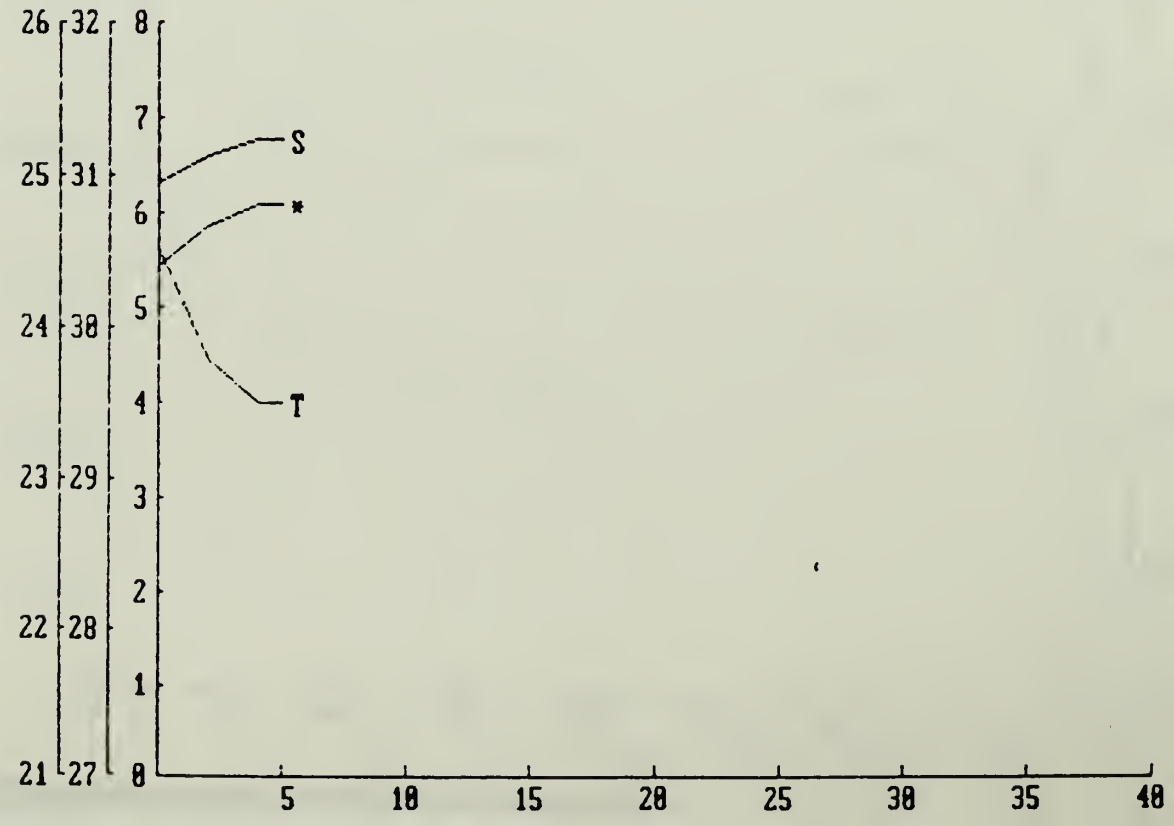


Figure 7 (cont.)

Somes Sound Cruise 1 April 15, 1986 Station # 20
44 21.5 N 68 18.6 W



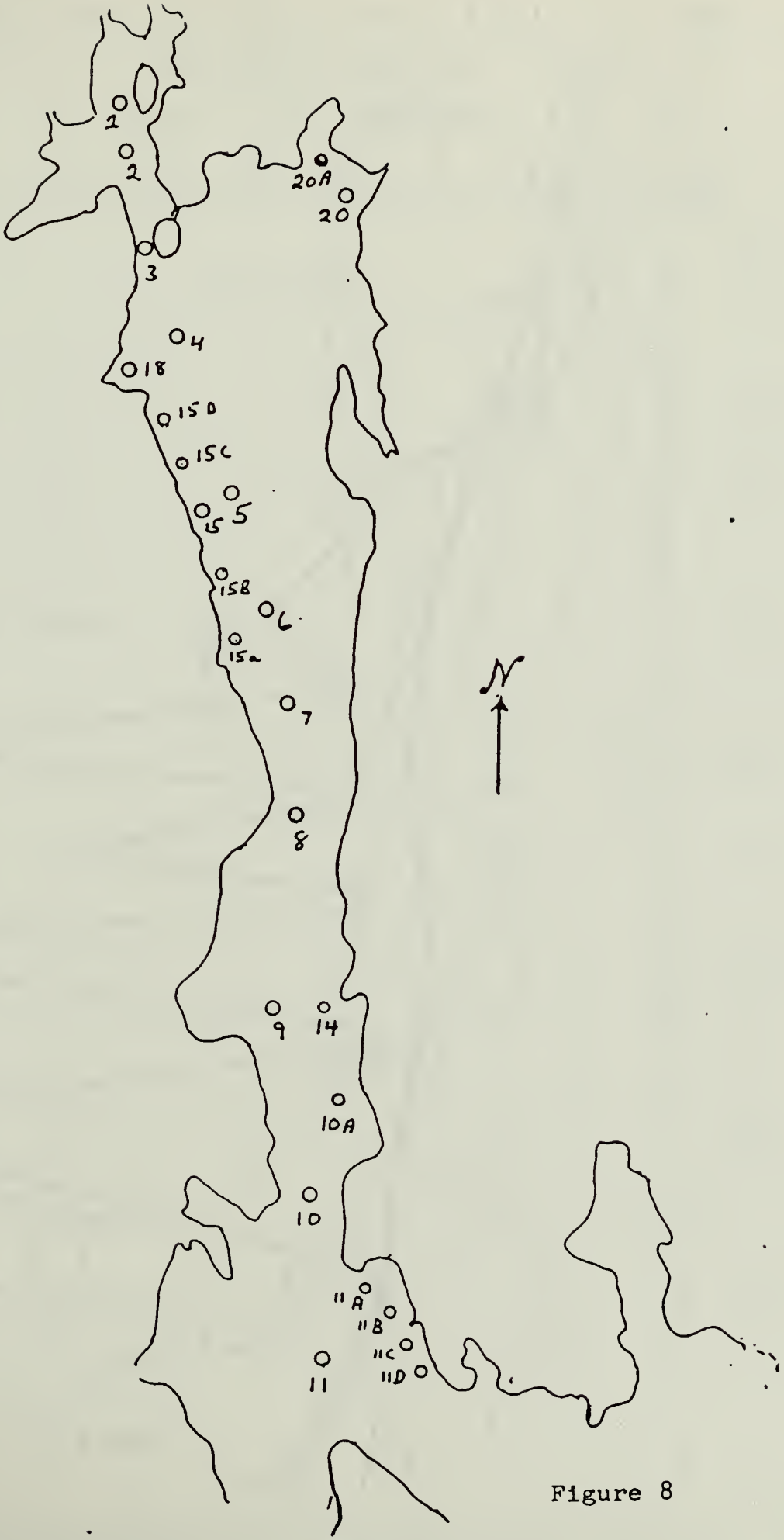

1
2
20A
20
3
4
18
15D
15C
5
15
15B
6
15a
7
N
8
9
14
10A
10
11A
11B
11C
11D
11
1

Figure 8

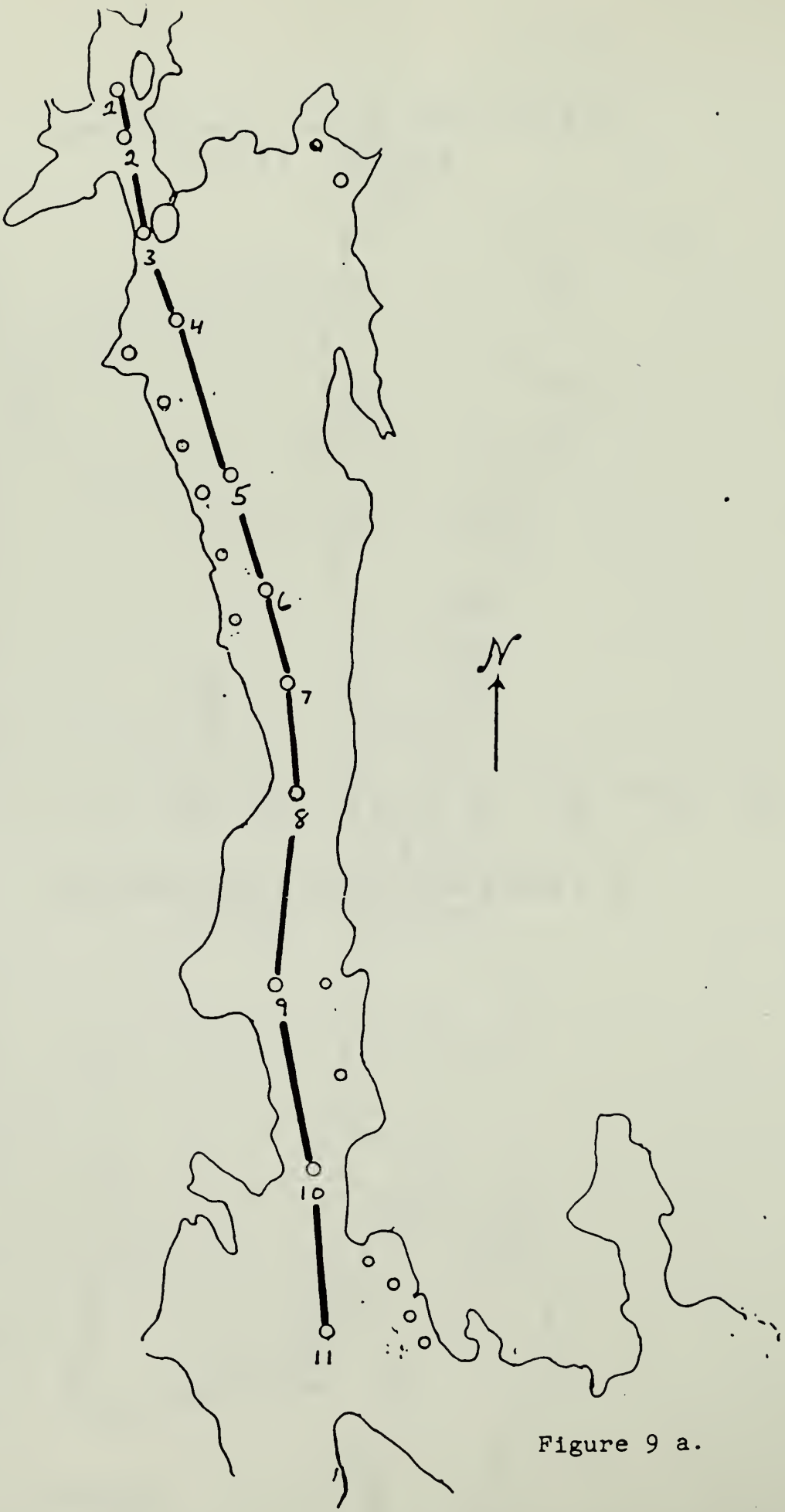
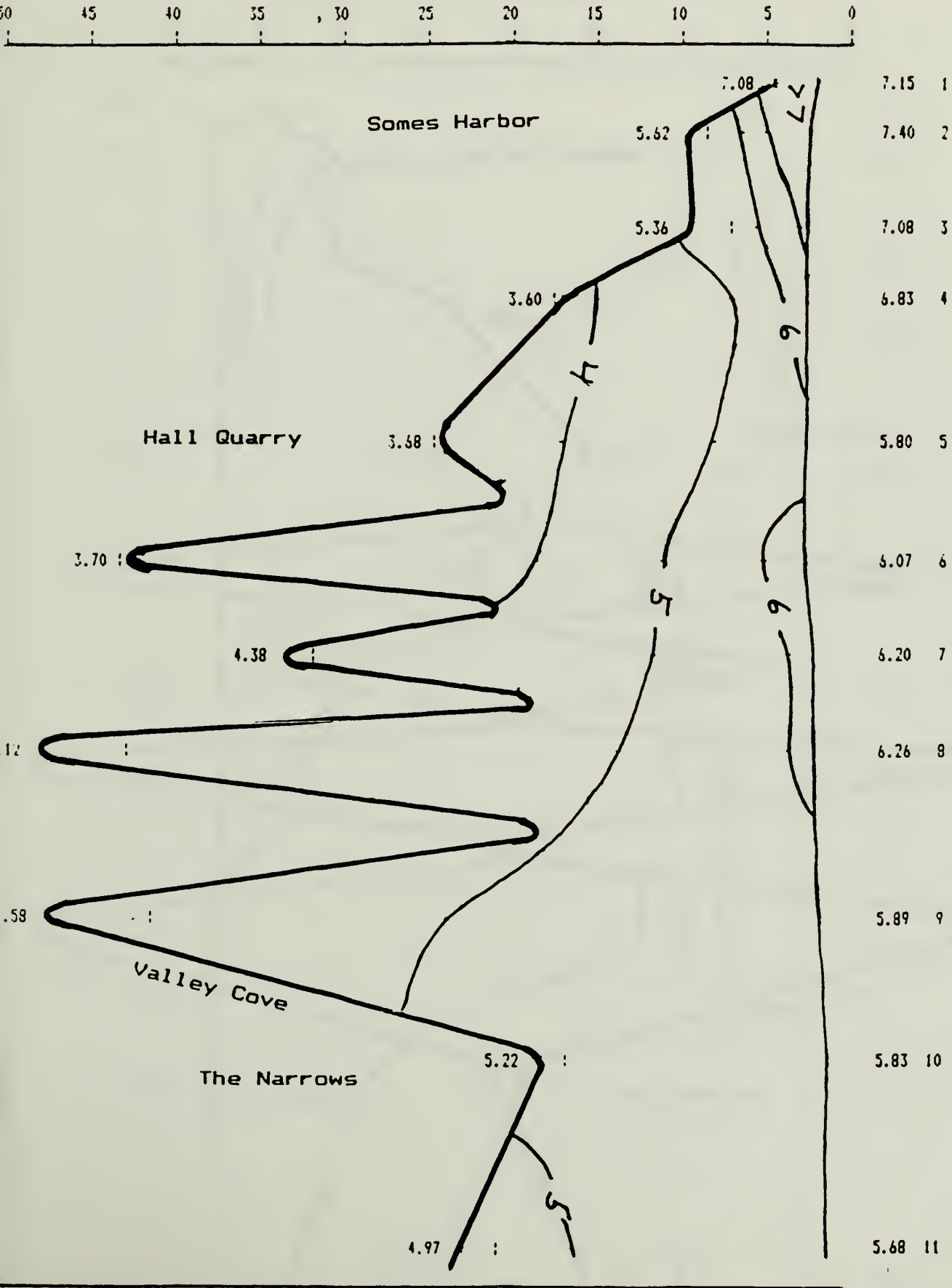


Figure 9 a.

Somes Sound Cruise II April 19

Temperature

Base = 0.00 Interval = 1.0



Somes Sound Cruise II April 19, 1986

Salinity

Base = 24.00 Interval = 0.5

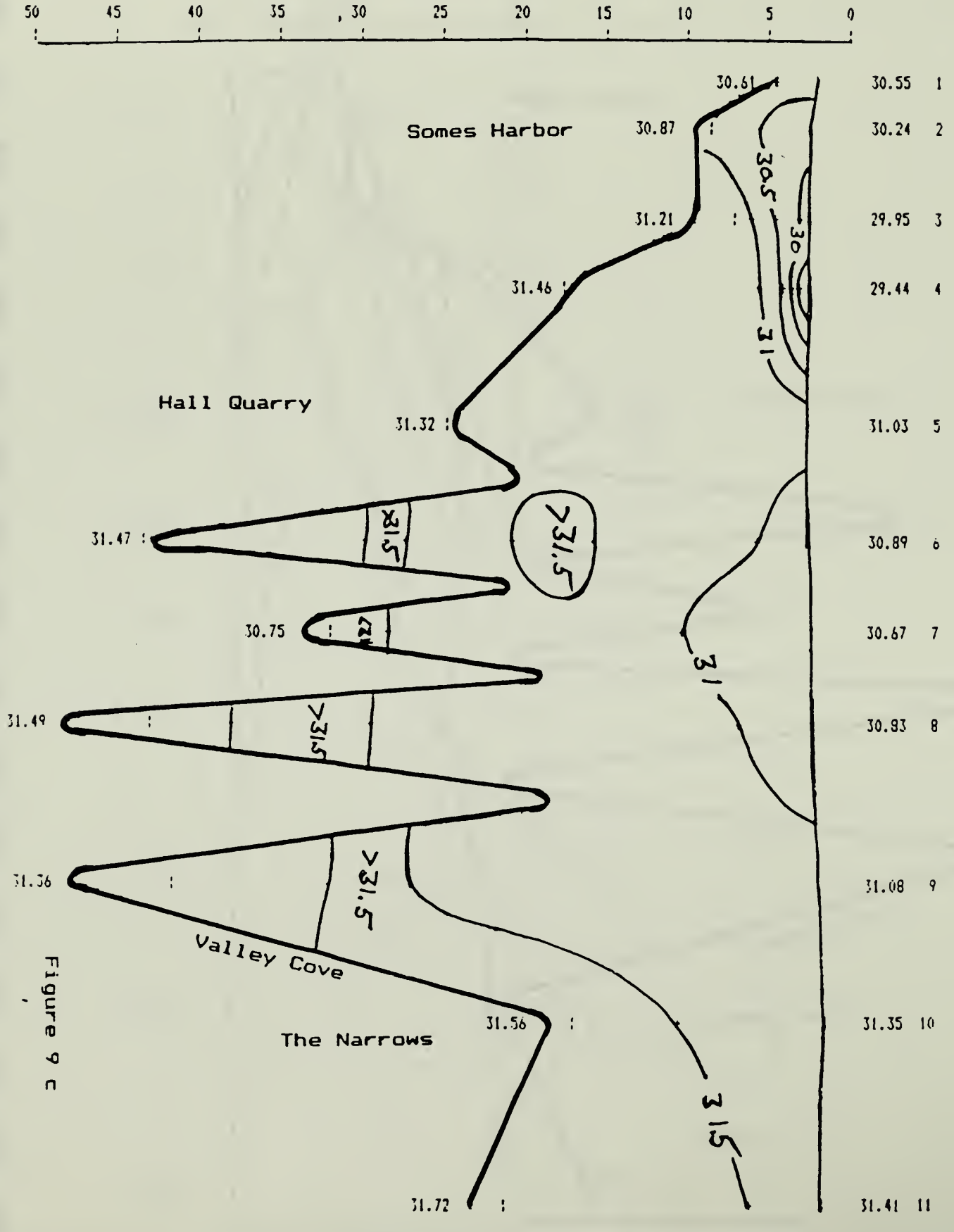


Figure 9 c

Somes Sound Cruise II — April 19

Sigma-t

Base = 22.00 Interval = 0.5

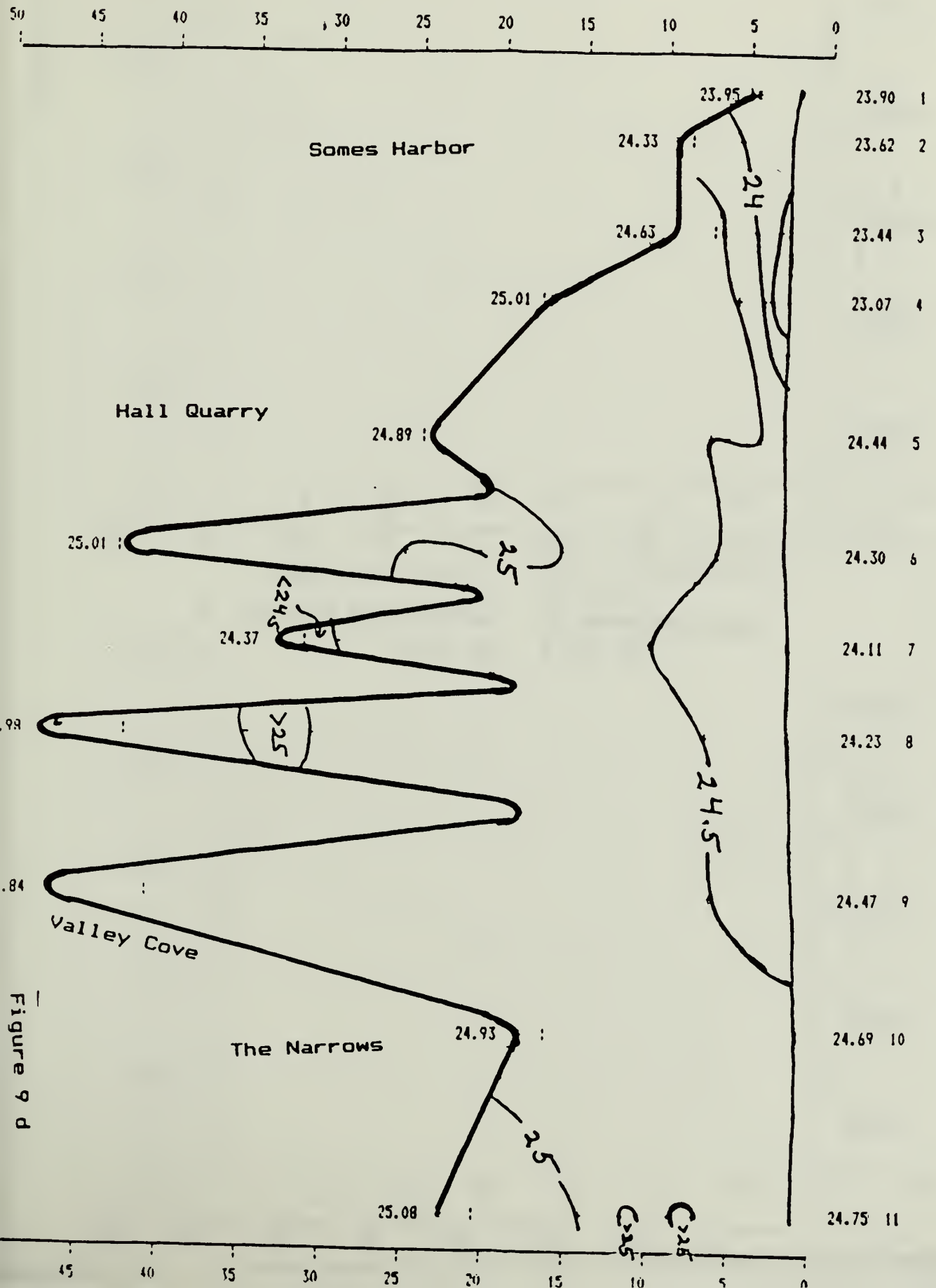


Figure 6 d

Somes Sound Cruise II April 19, 1986 Station # 1
44 21.8 N 68 19.7 W

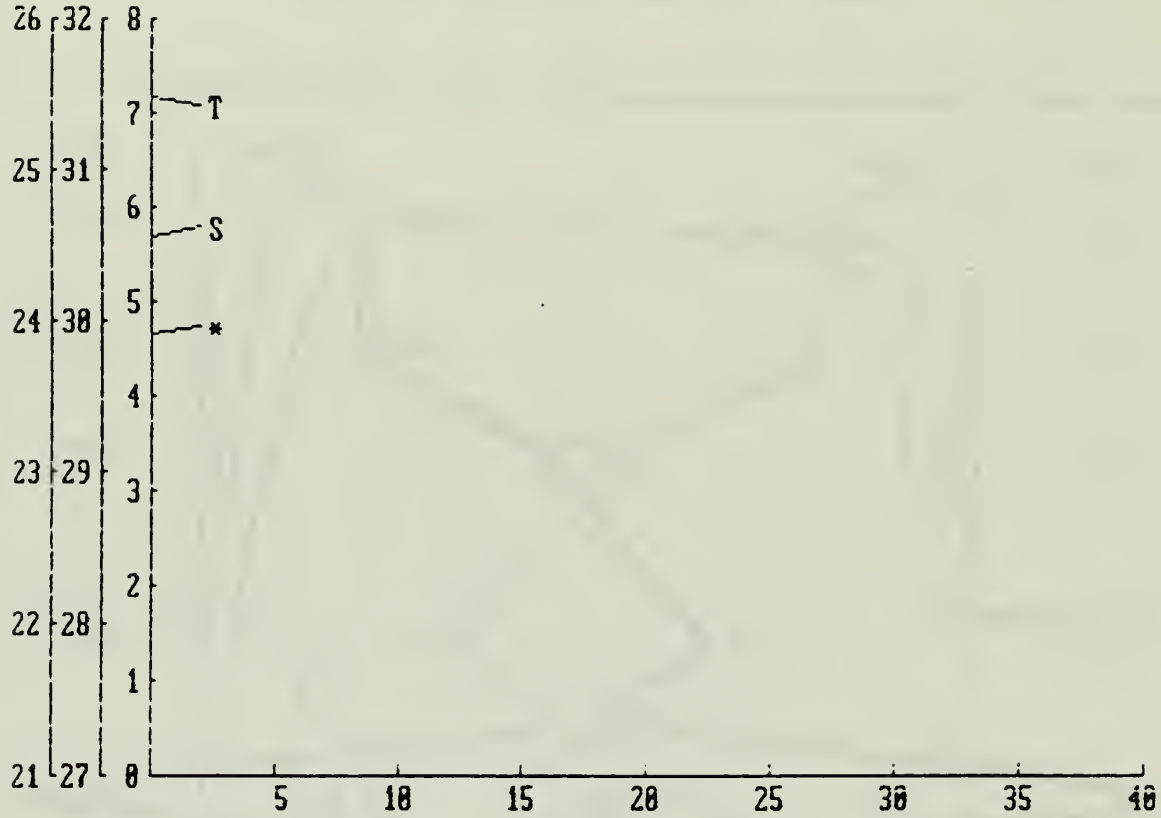
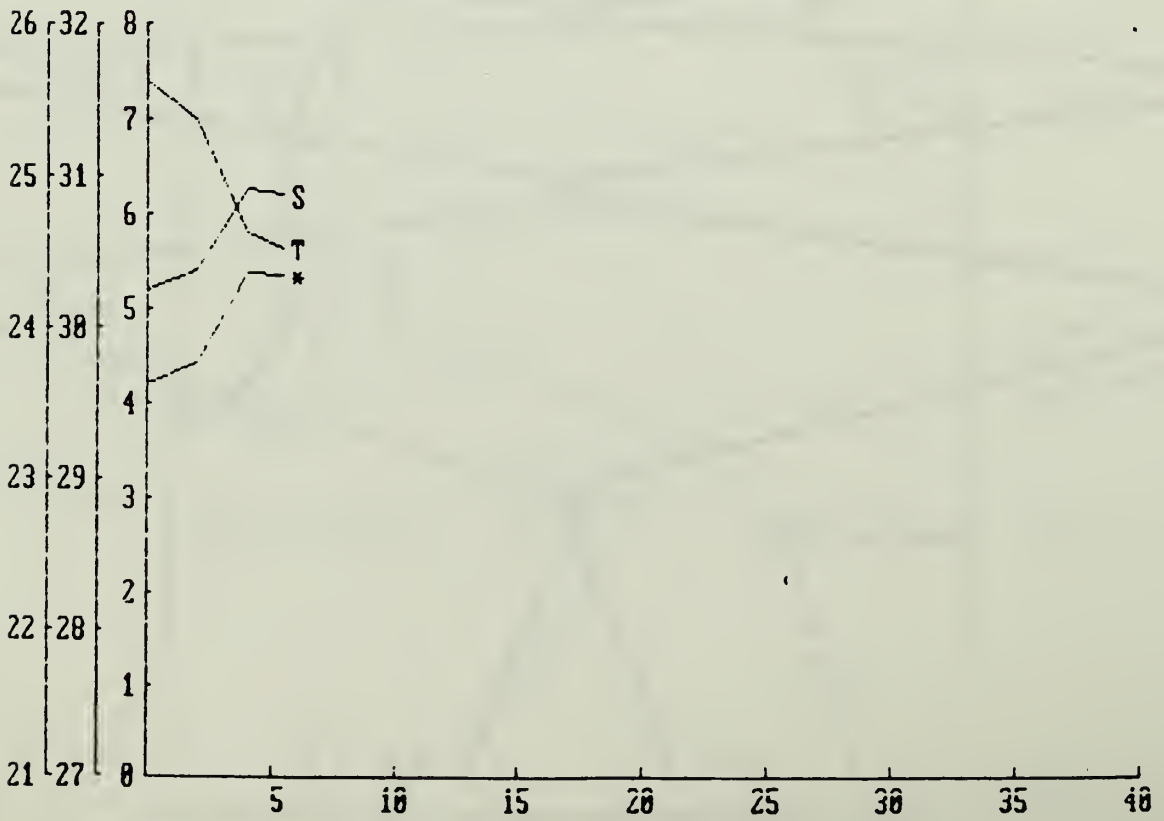
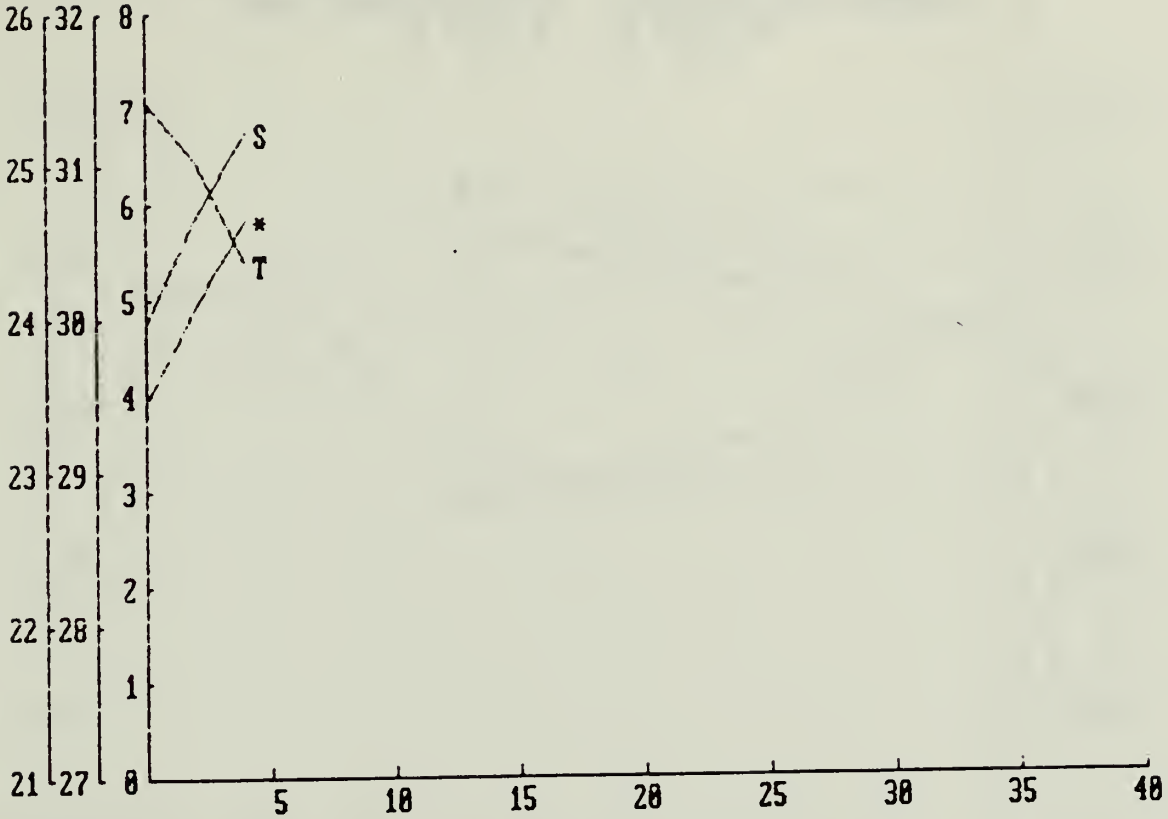


Figure 10

Somes Sound Cruise II April 19, 1986 Station # 2
44 21.7 N 68 19.6 W



Somes Sound Cruise II April 19, 1986 Station # 3
44 21.3 N 68 19.5 W



Somes Sound Cruise II April 19, 1986 Station # 4
44 21.8 N 68 19.4 W

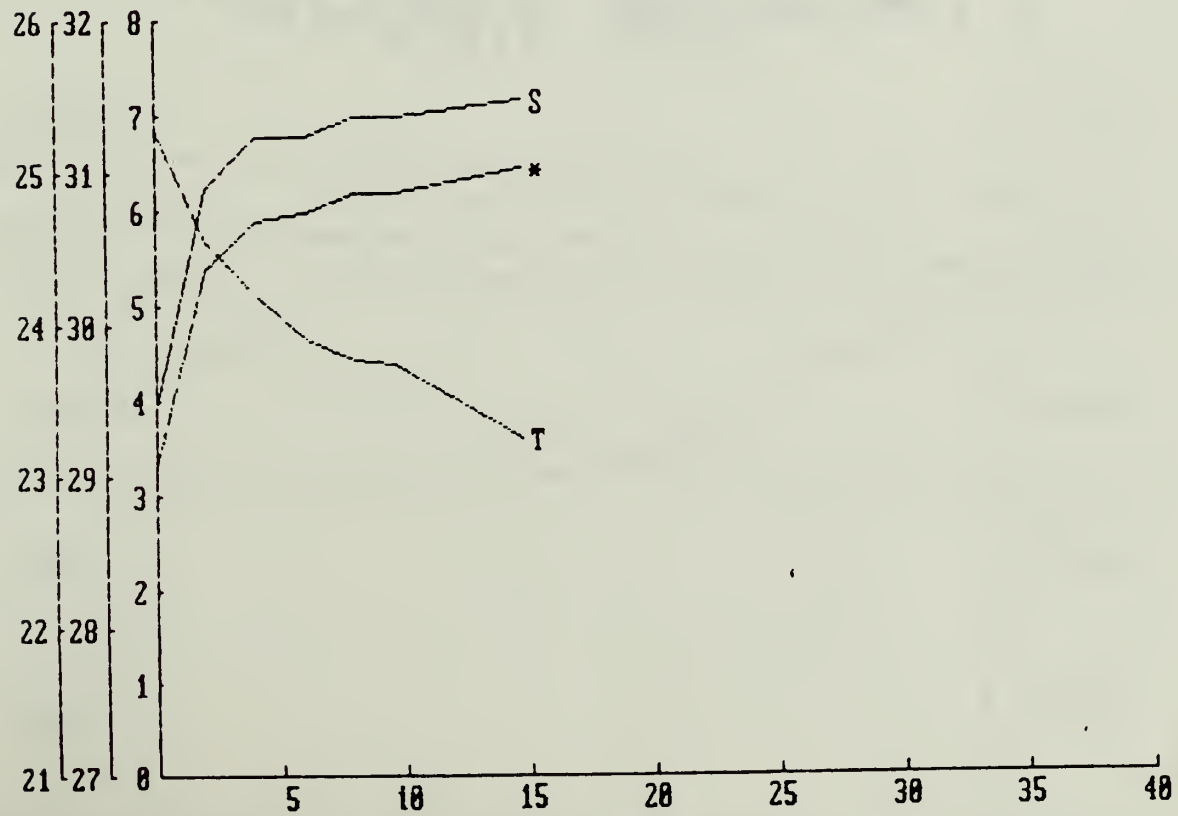
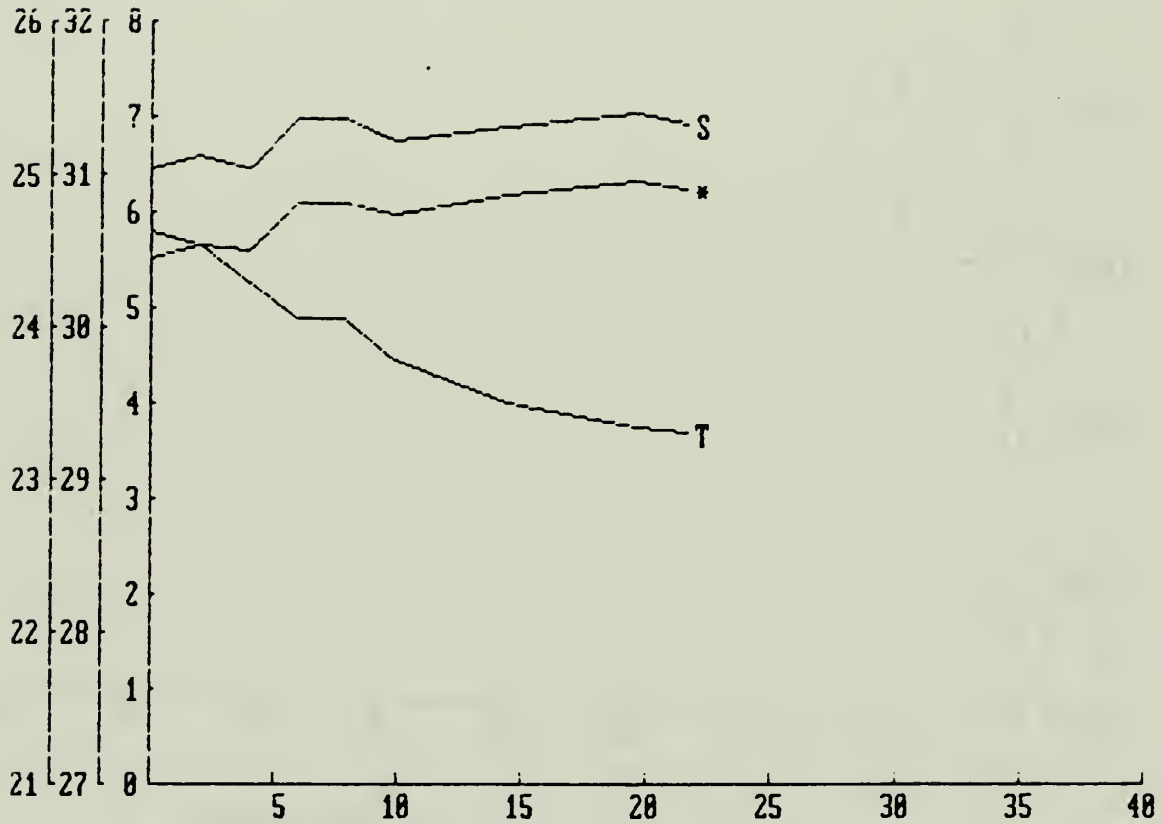


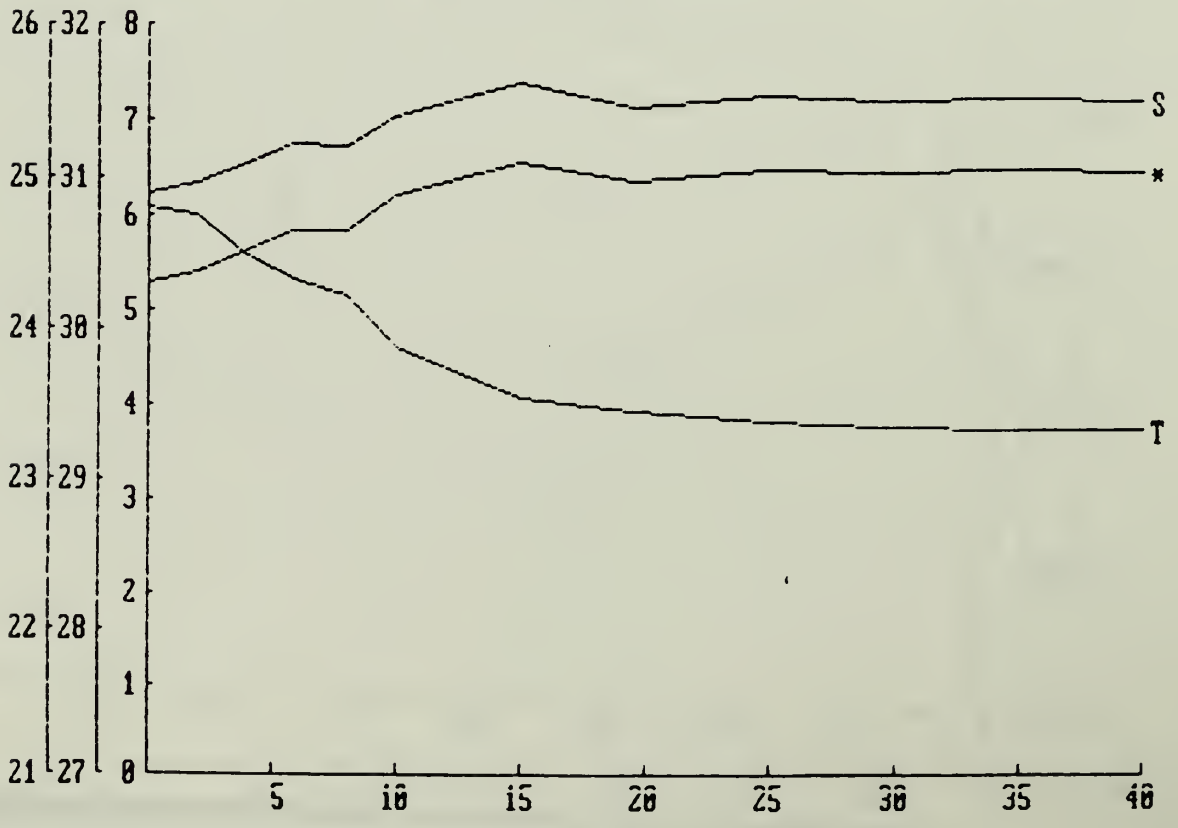
Figure 10 (cont.) -

Figure 10 (cont.)

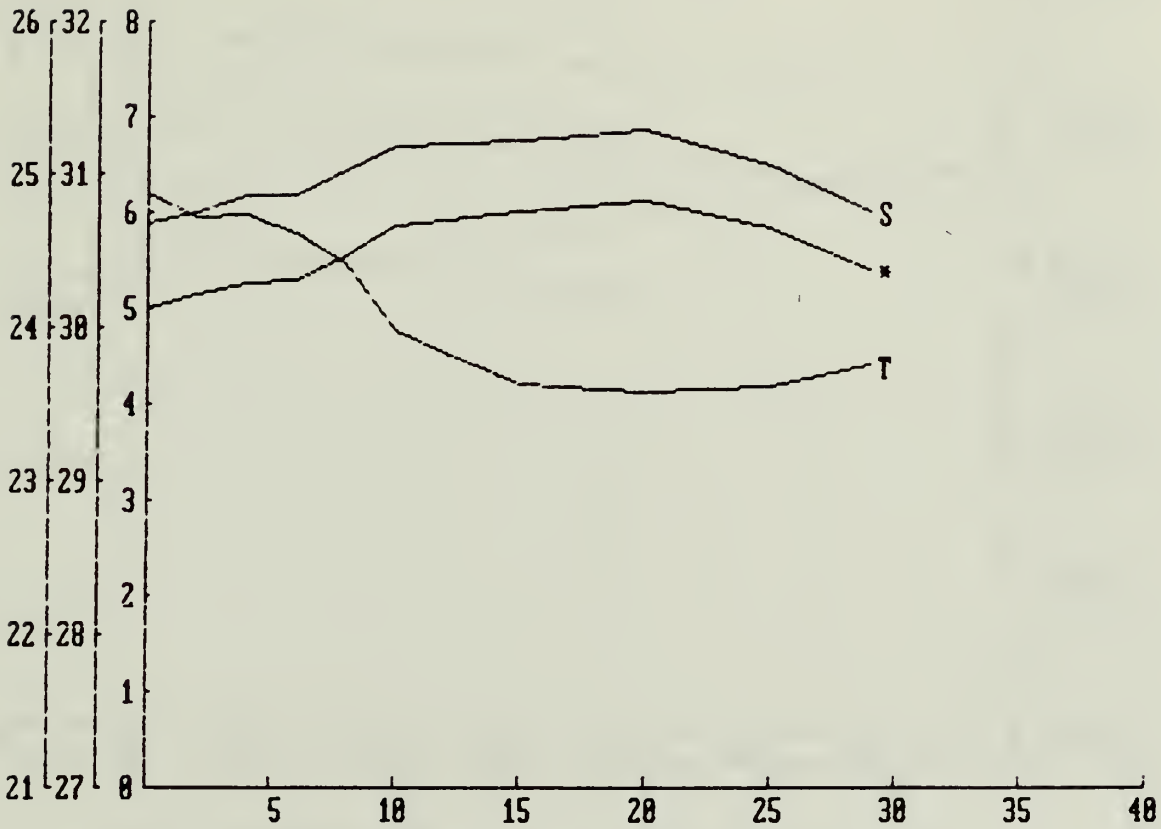
Somes Sound Cruise II April 19, 1986 Station # 5
44 20.4 N 68 19.2 W



Somes Sound Cruise II April 19, 1986 Station # 6
44 20.0 N 68 18.9 W



Somes Sound Cruise II April 19, 1986 Station # 7
44 19.7 N 68 18.8 W



Somes Sound Cruise II April 19, 1986 Station # 8
44 19.3 N 68 18.8 W

Figure 10 (cont.)

Somes Sound Cruise II April 19, 1986 Station # 9
44 18.6 N 68 18.8 W

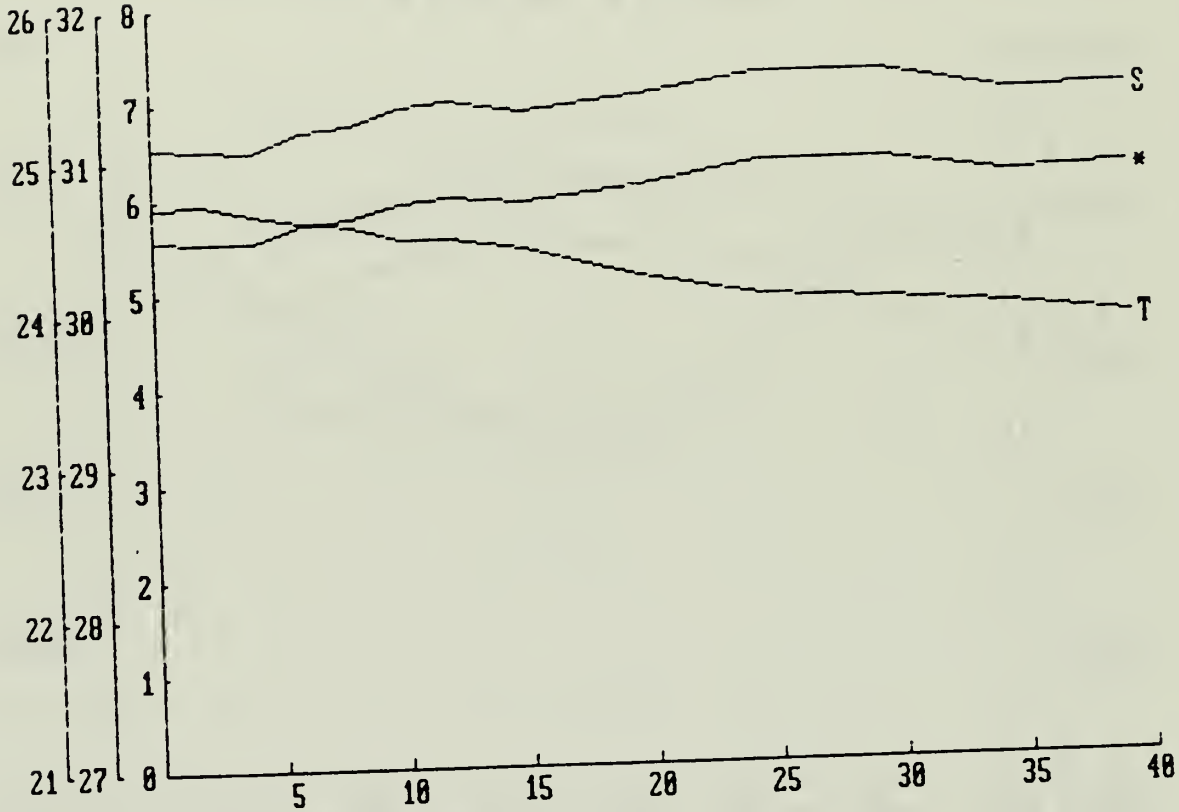
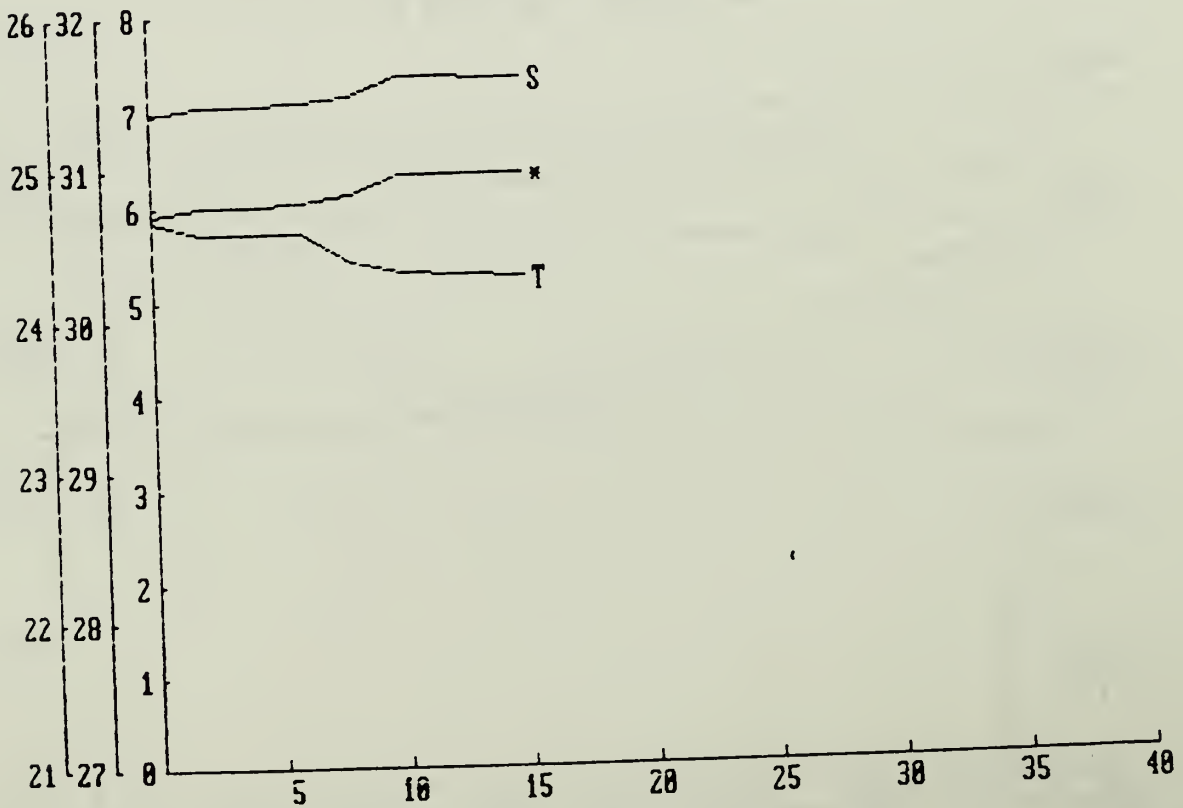


Figure 10 (cont.)

Somes Sound Cruise II April 19, 1986 Station # 10
44 18.1 N 68 18.6 W



Somes Sound Cruise II April 19, 1986 Station # 11
44 17.3 N 68 18.5 W

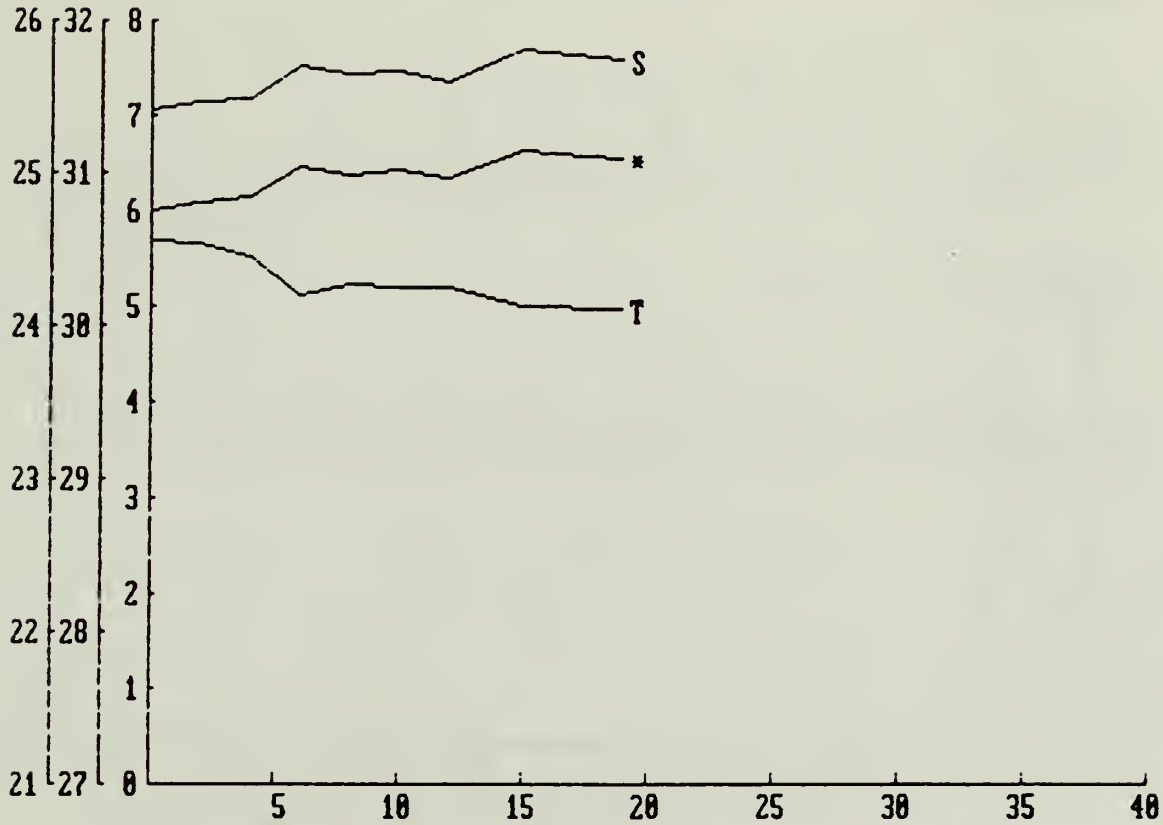
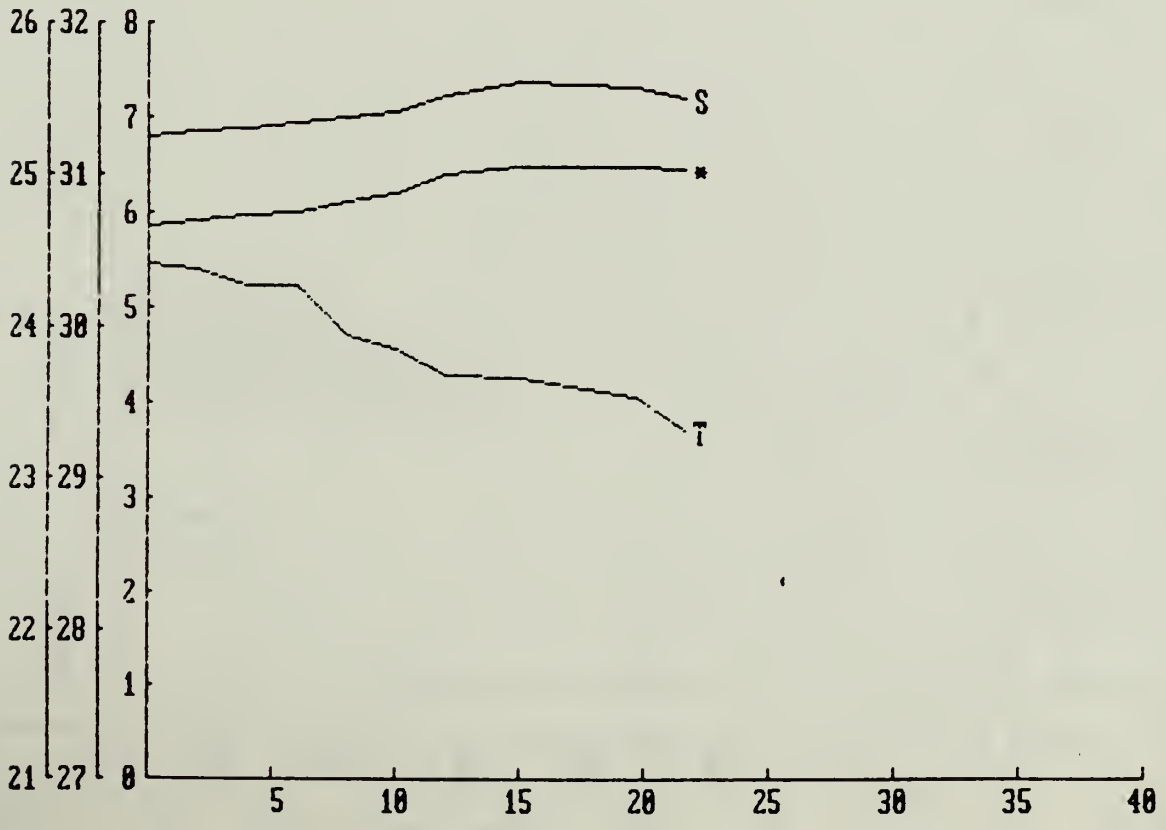


Figure 10 (cont.)

Somes Sound Cruise II April 19, 1986 Station # 15
44 20.4 N 68 19.3 W



Somes Sound Cruise II April 19, 1986 Station # 18
44 20.8 N 68 19.6 W

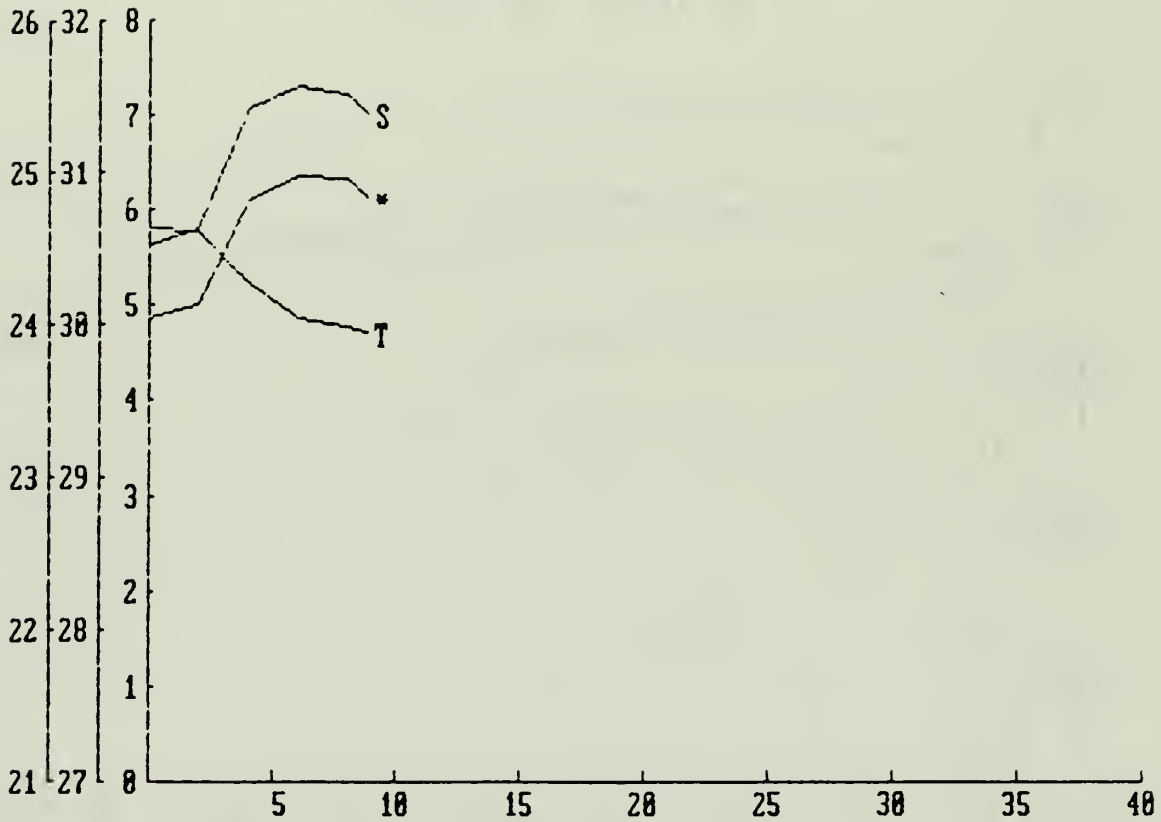
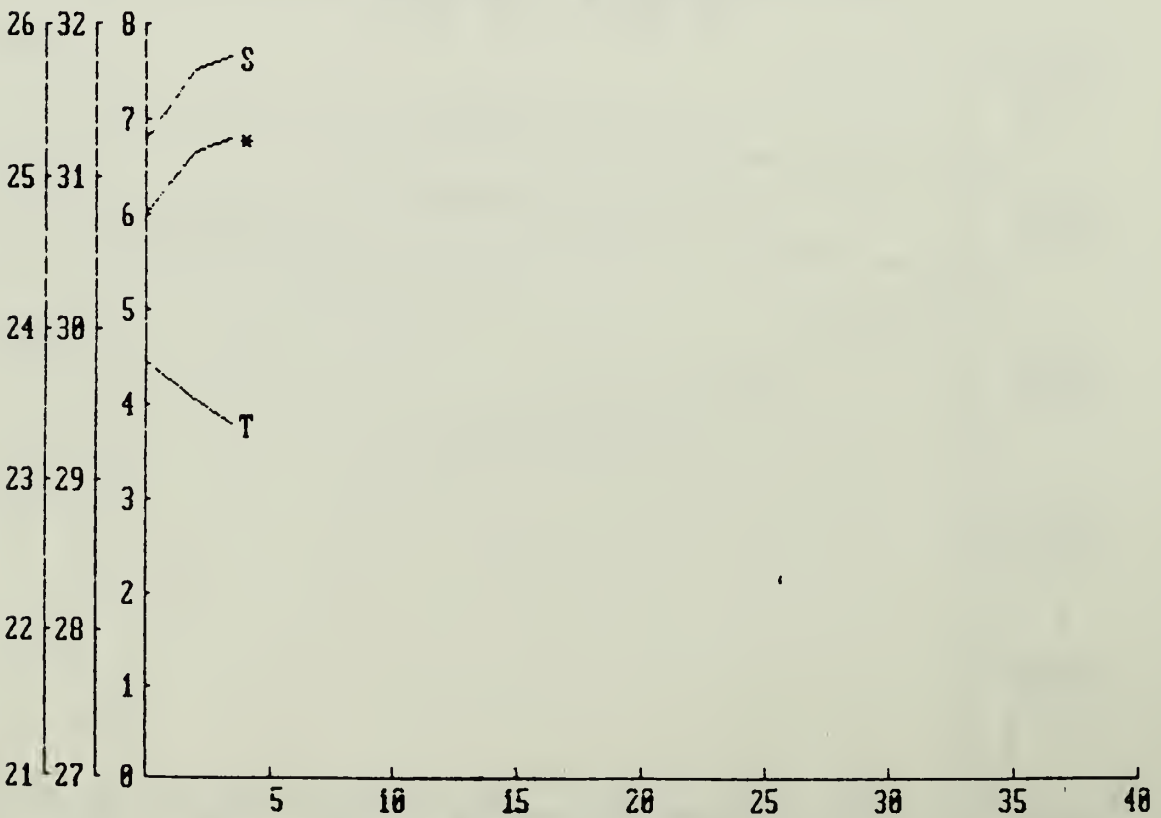


Figure 10 (cont.)

Somes Sound Cruise II April 19, 1986 Station # 20
44 21.5 N 68 18.6 W



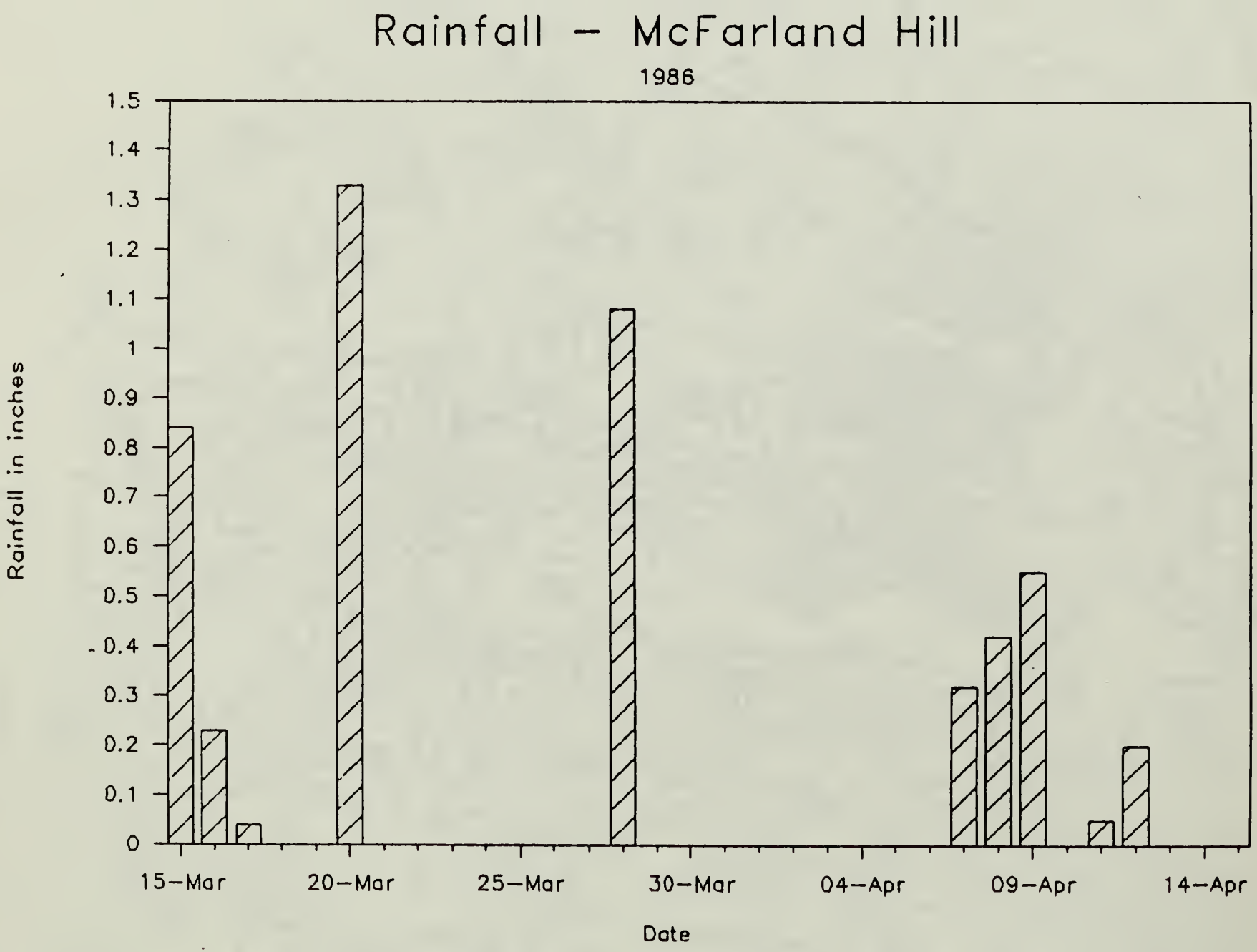

Rainfall – McFarland Hill
1986
Rainfall in inches
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
15–Mar
20–Mar
25–Mar
30–Mar
04–Apr
09–Apr
14–Apr
Date

Figure 11

Somes Sound Drainage Areas

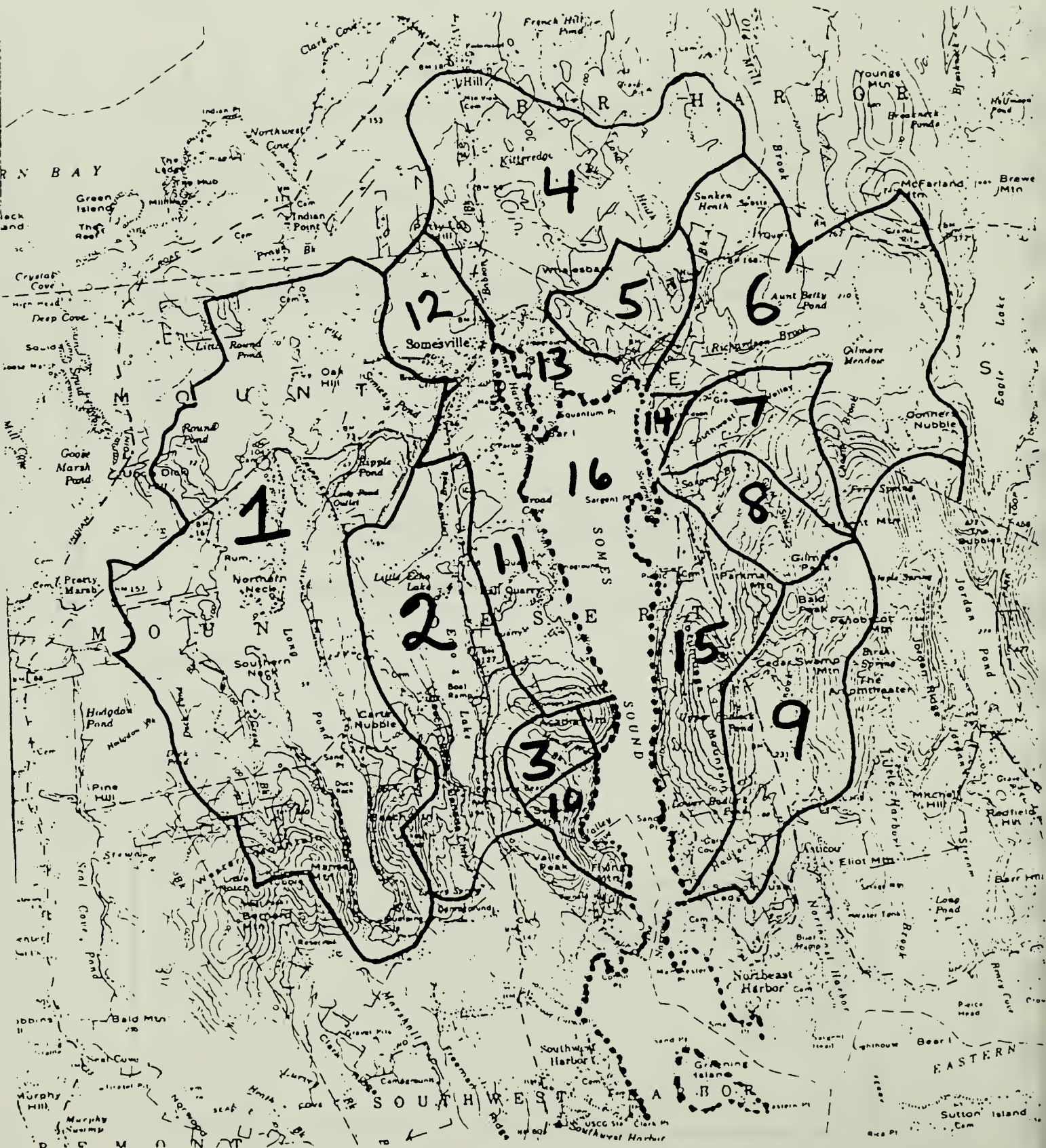


Figure 12

Volume Elements for Cruise I

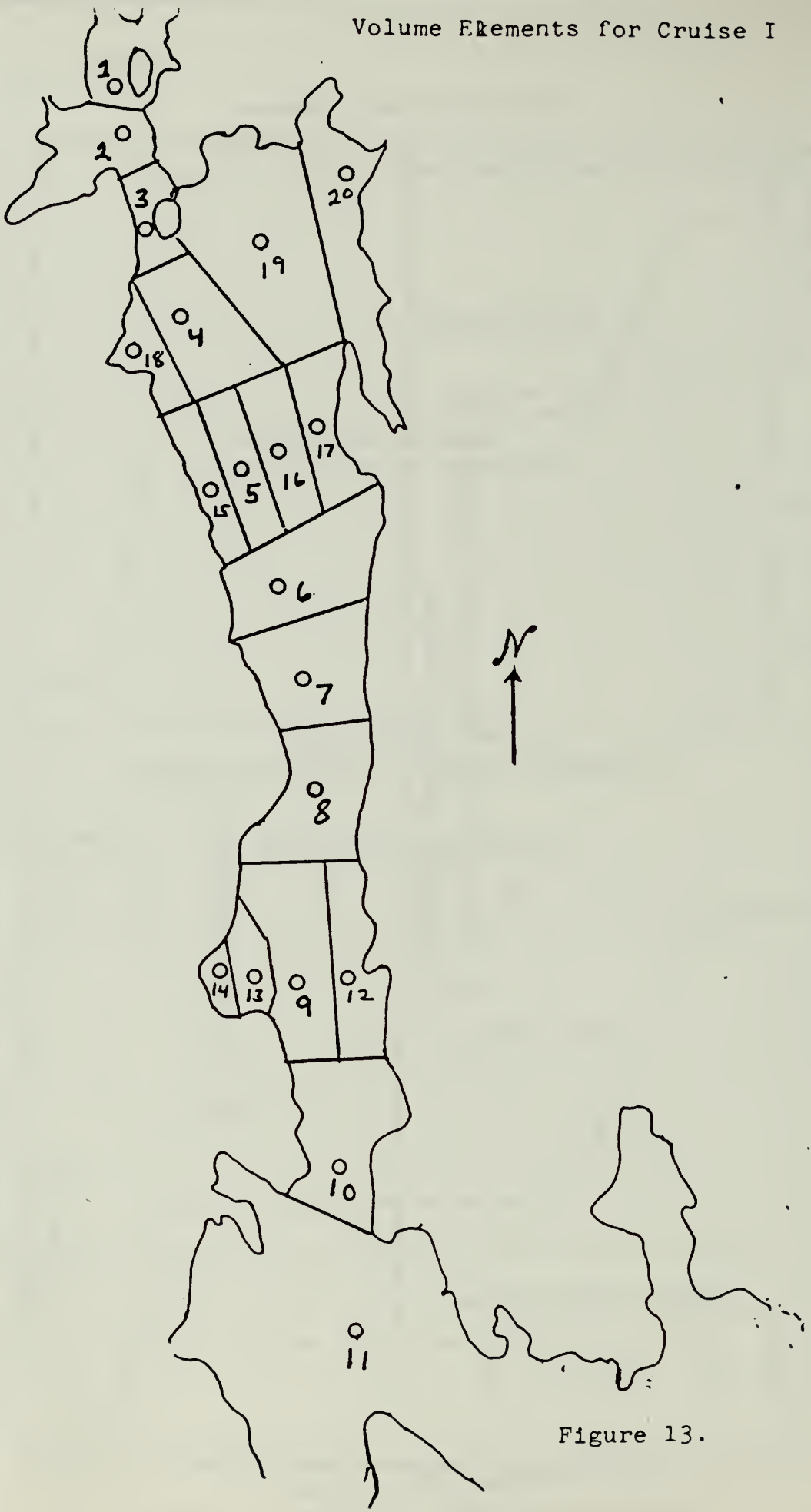


Figure 13.

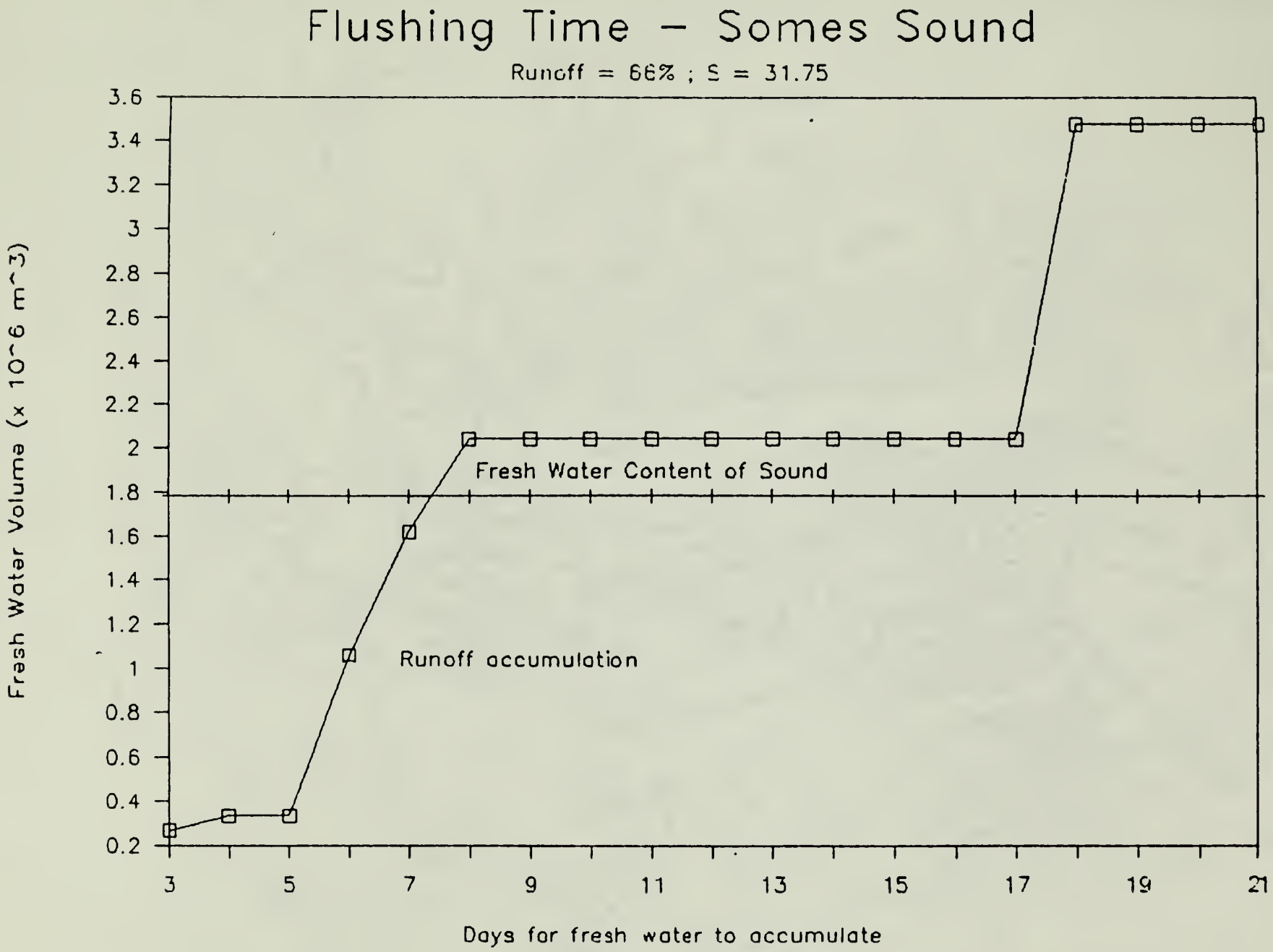

Flushing Time – Somes Sound
Runoff = 66% ; S = 31.75
Fresh Water Volume (x 10^6 m^3)
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
Fresh Water Content of Sound
Runoff accumulation
3
5
7
9
11
13
15
17
19
21
Days for fresh water to accumulate

Figure 14

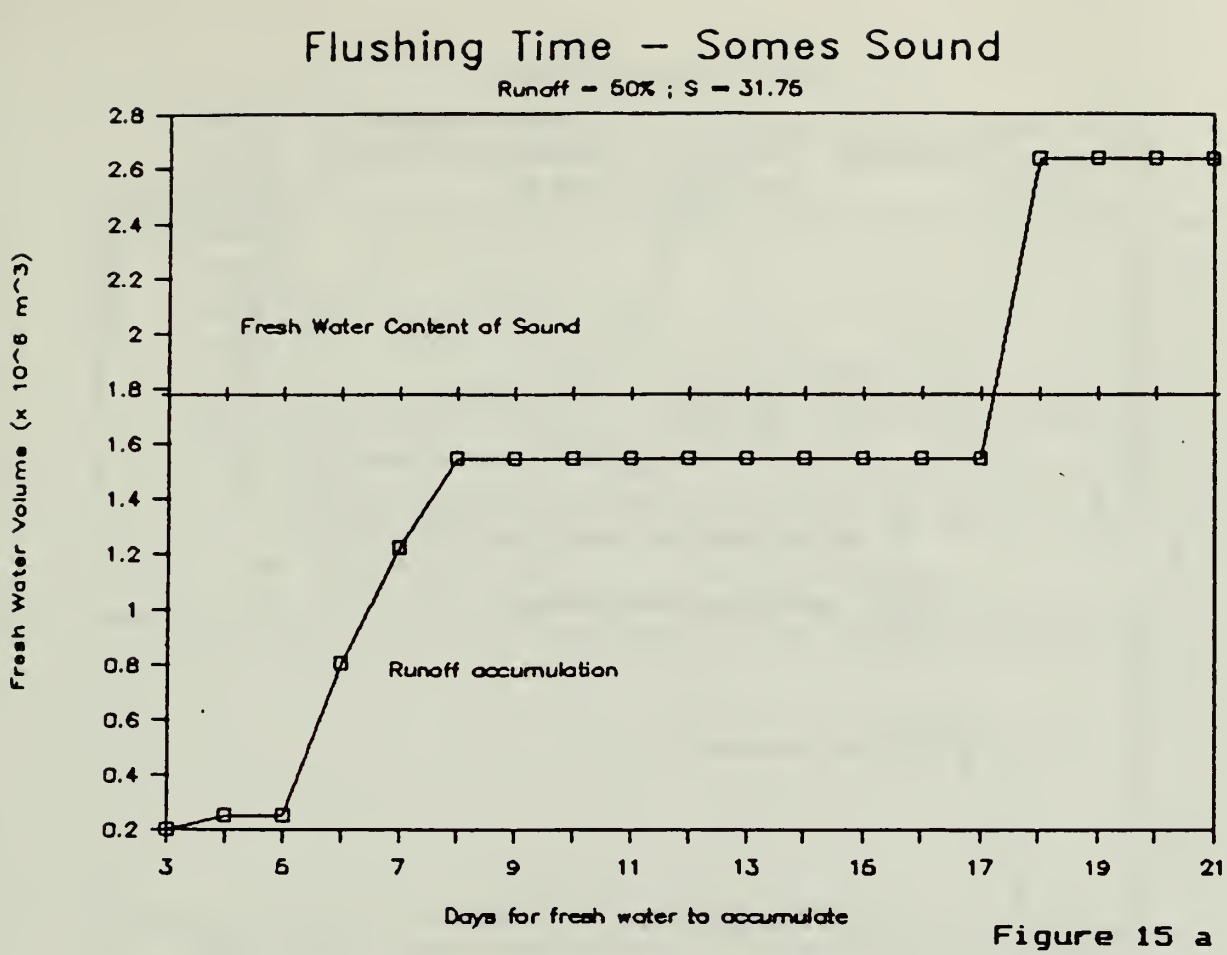


Figure 15 a

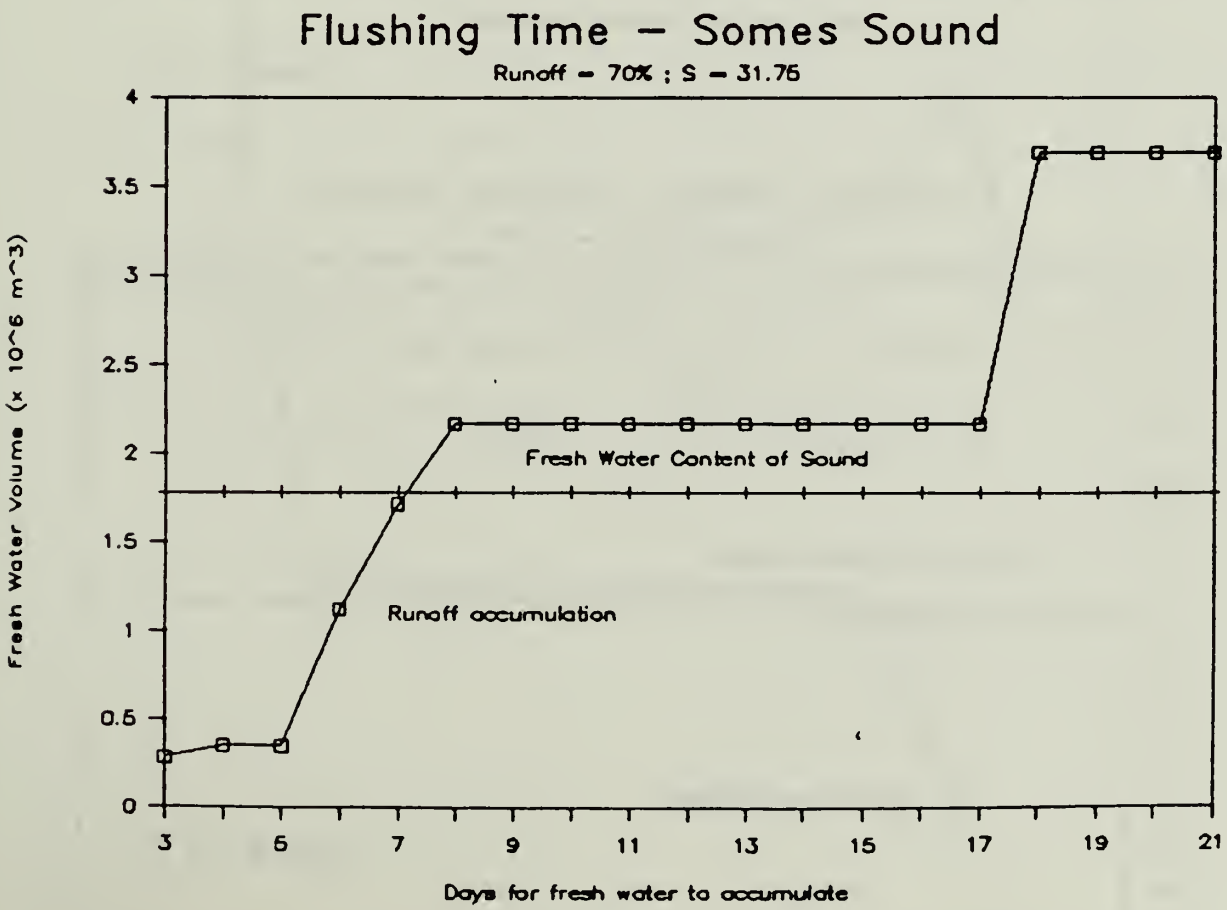


Figure 15 b

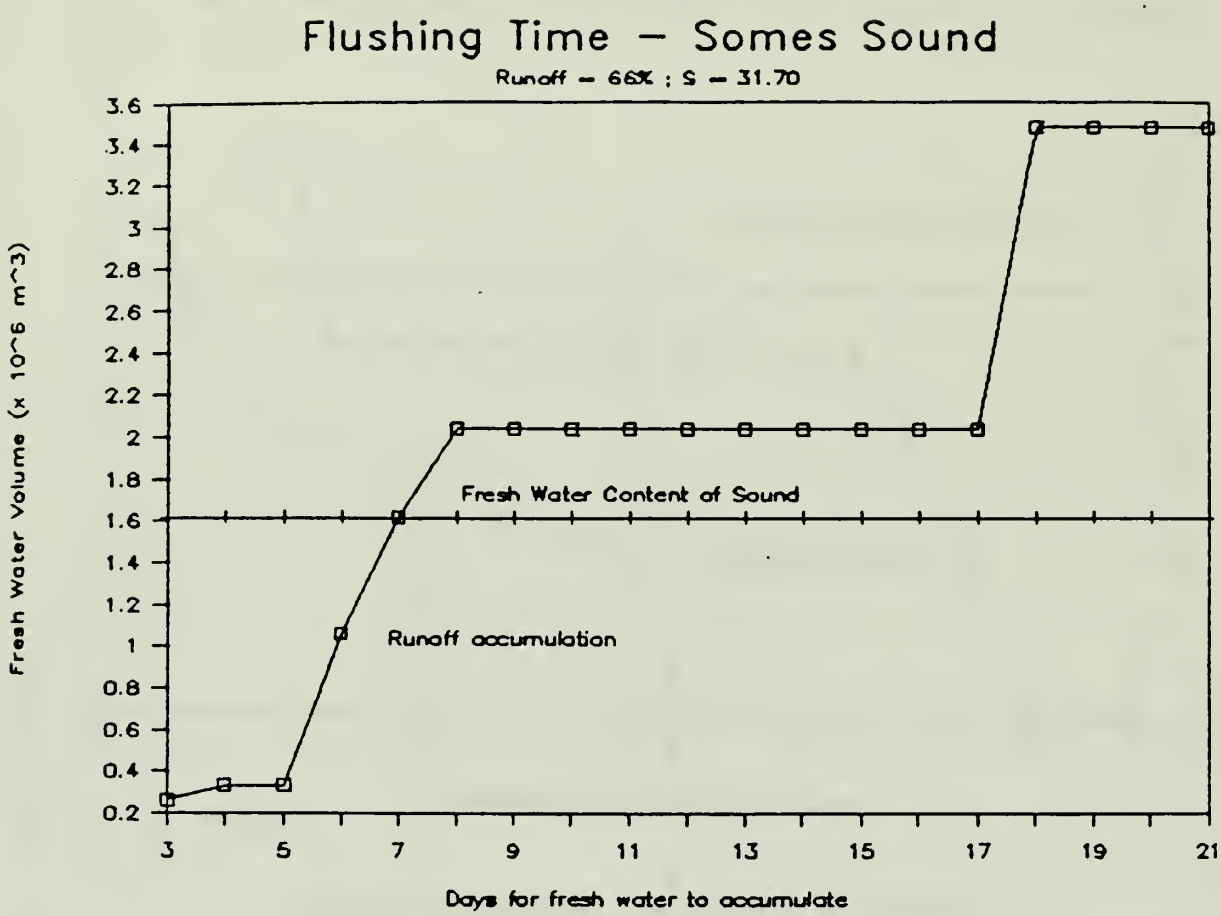

Flushing Time – Somes Sound
Runoff = 66% ; S = 31.70
Fresh Water Volume (x 10^6 m^3)
Fresh Water Content of Sound
Runoff accumulation
Days for fresh water to accumulate

Figure 16 a

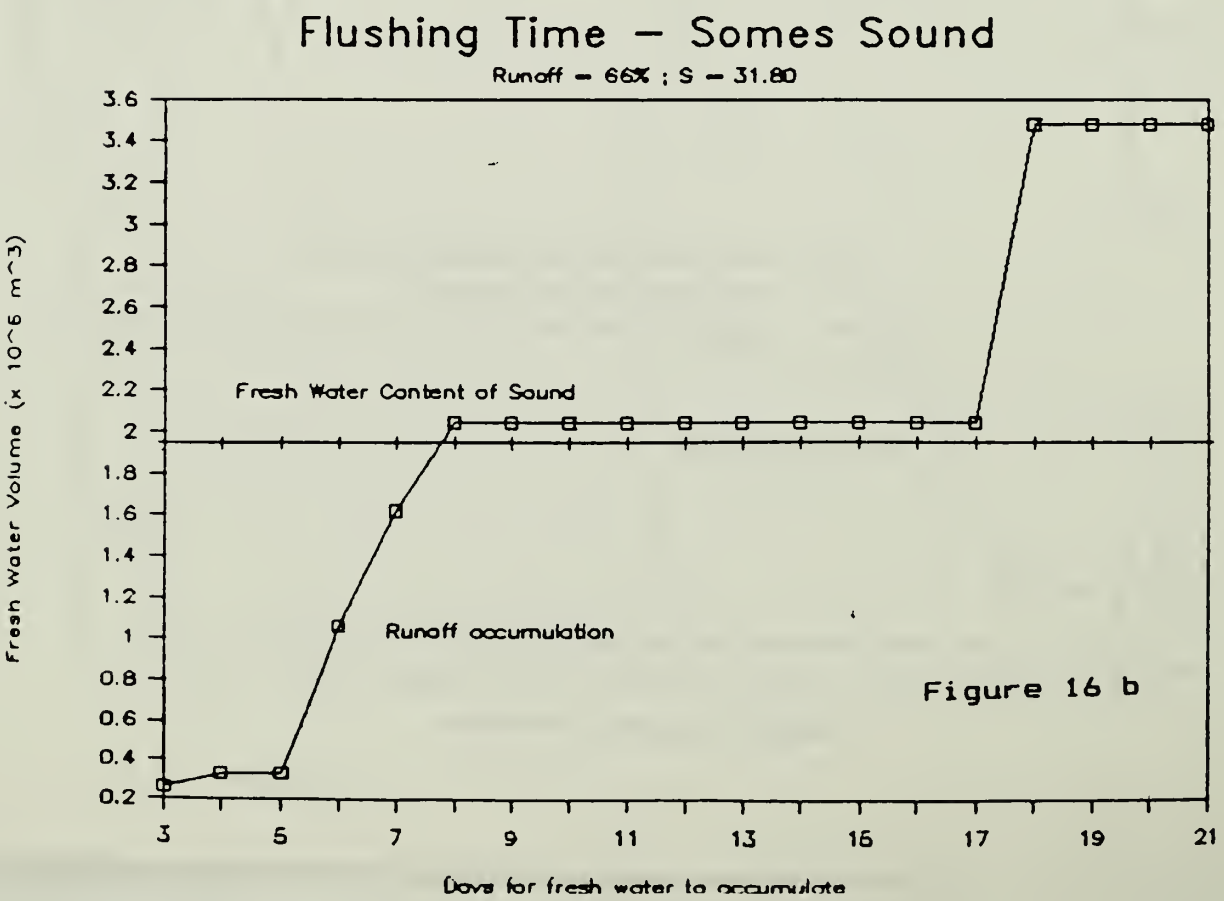

Flushing Time – Somes Sound
Runoff = 66% ; S = 31.80
Fresh Water Volume (x 10^6 m^3)
Fresh Water Content of Sound
Runoff accumulation
Days for fresh water to accumulate

Figure 16 b

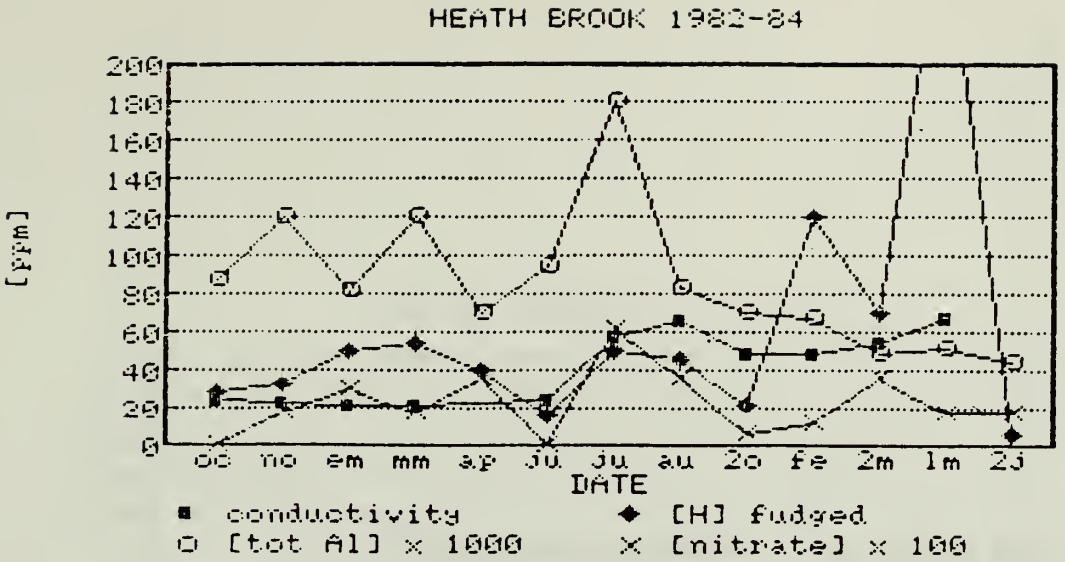


Figure 17 a

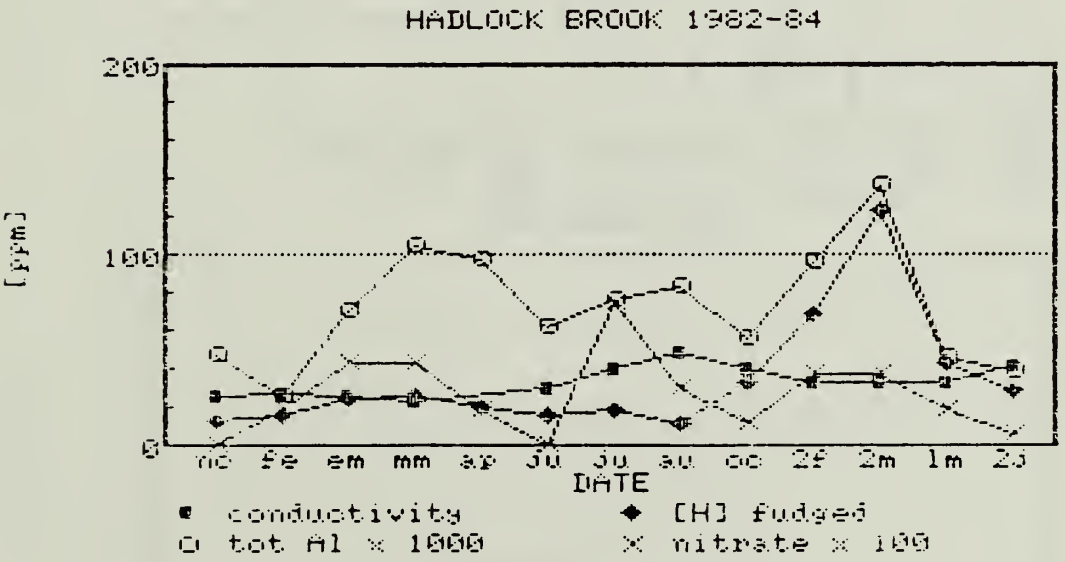


Figure 17 b

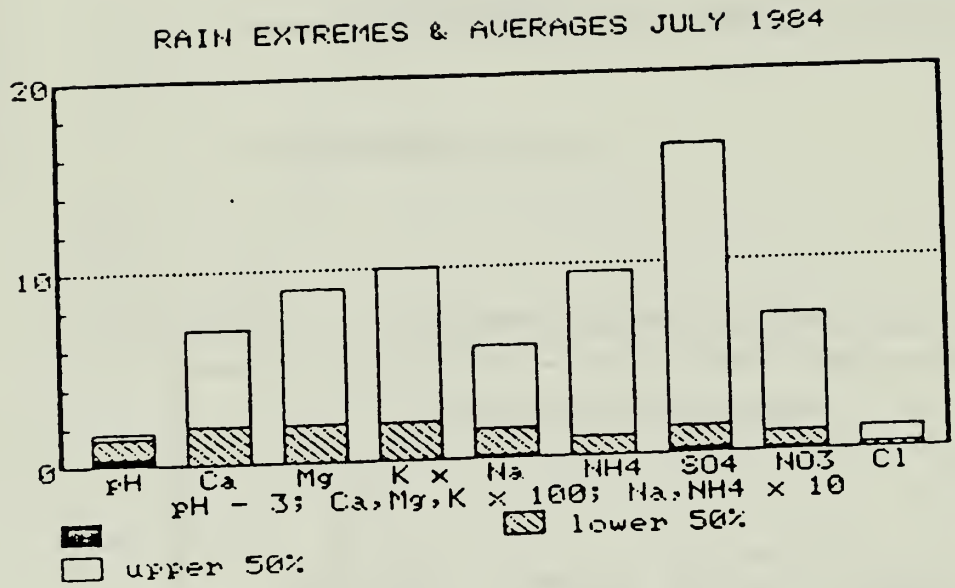

RAIN EXTREMES & AVERAGES JULY 1984
20
10
0
pH
Ca
Mg
K x
Na
NH4
SO4
NO3
Cl
pH - 3; Ca,Mg,K x 100; Na,NH4 x 10
lower 50%
upper 50%

Figure 18

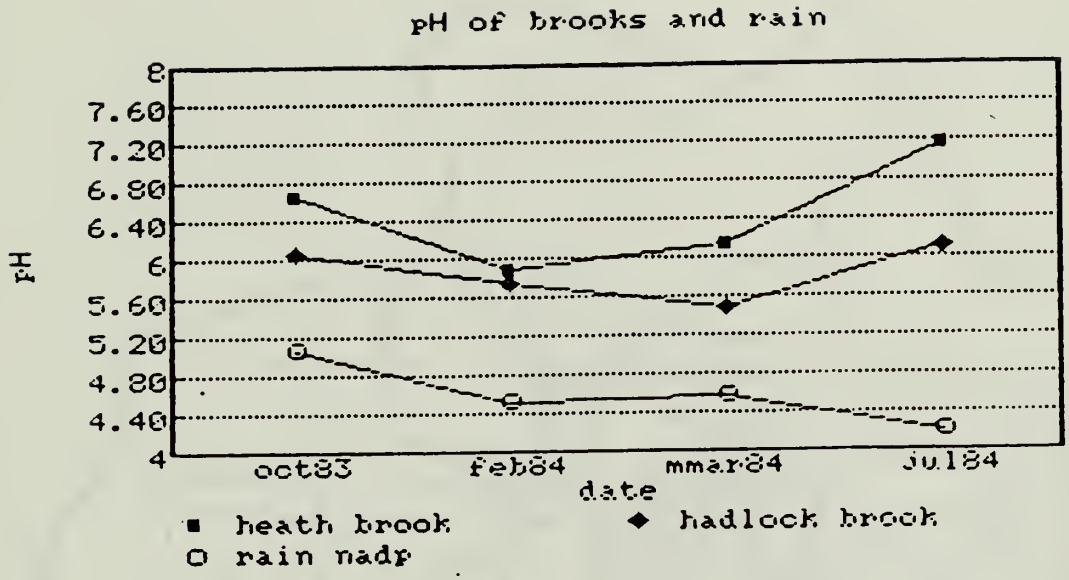


Figure 19 a

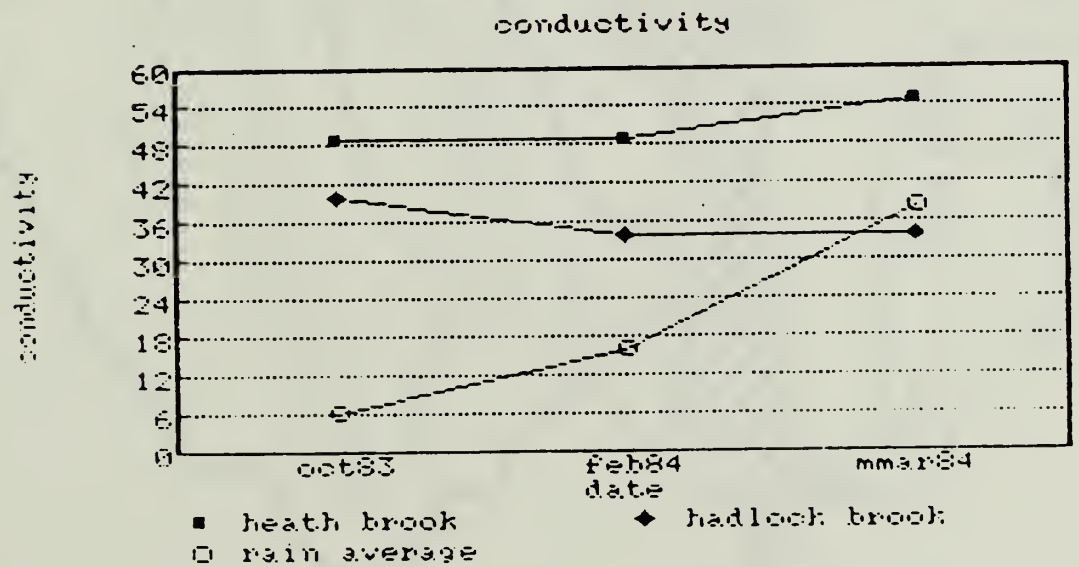


Figure 19 b

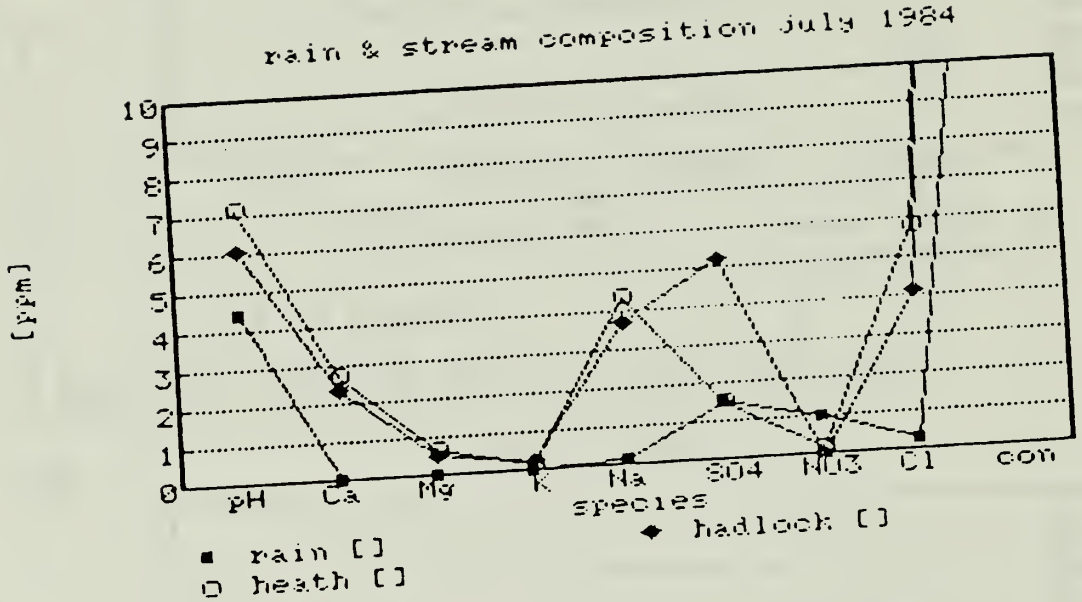

rain & stream composition July 1984
[ppm]
10
9
8
7
6
5
4
3
2
1
0
pH
Ca
Mg
K
Na
SO4
NO3
Cl
cond
species
rain []
heath []
hadlock []

Figure 20

SOMES SOUND WATERSHEDS

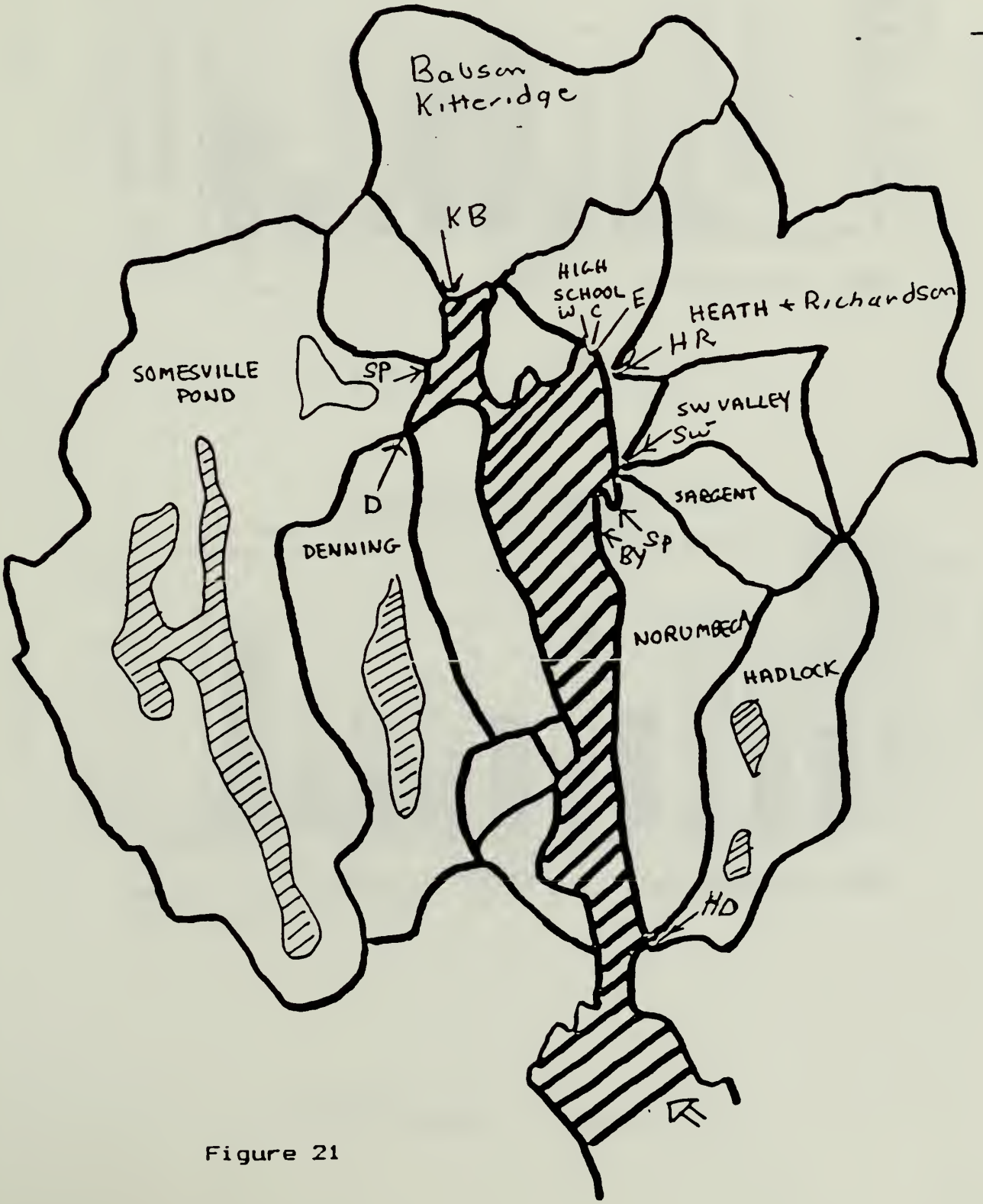


Figure 21

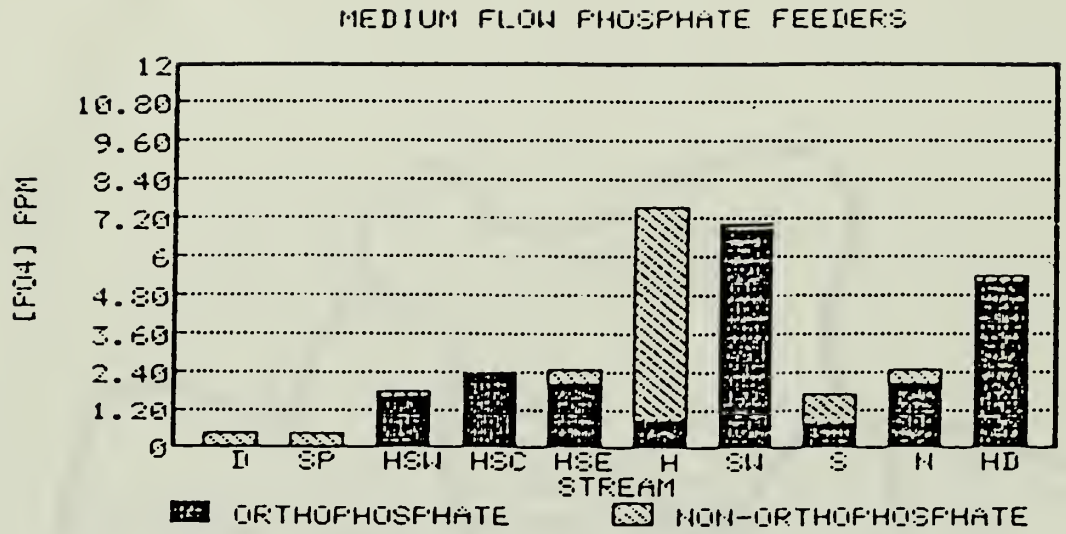


Figure 22 a

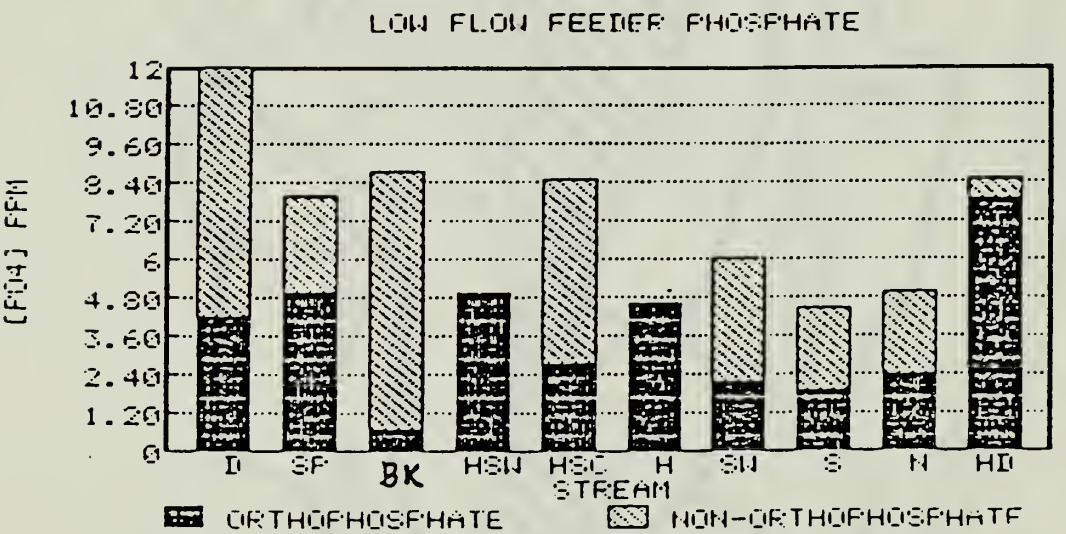


Figure 22 b.

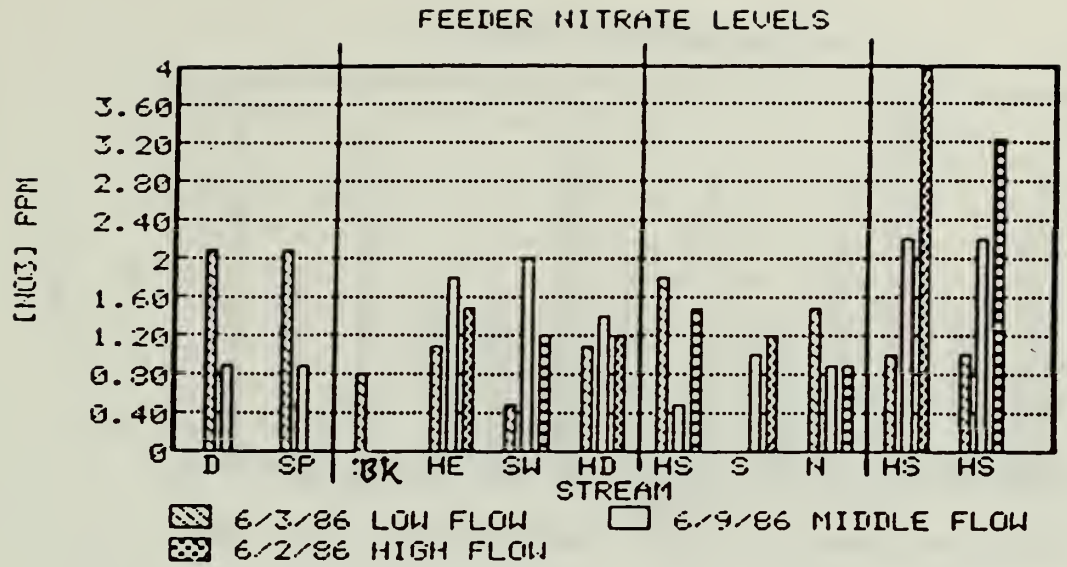


Figure 23 a

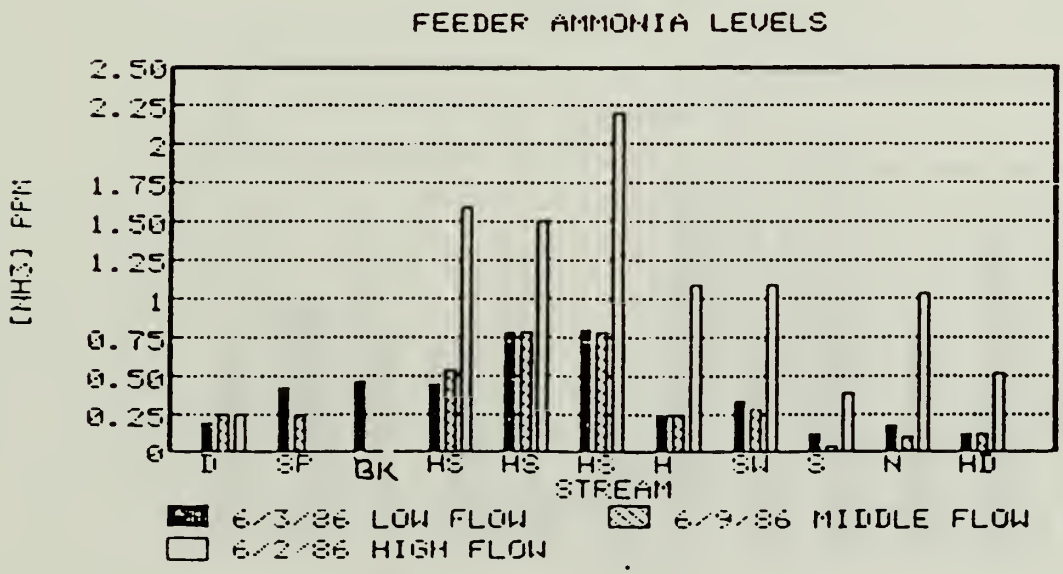


Figure 23 b

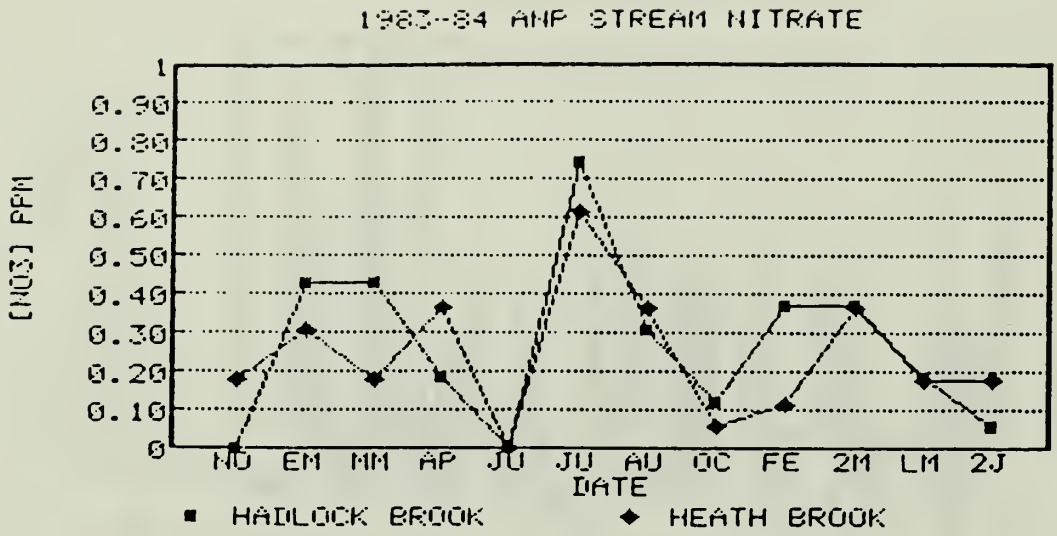


Figure 24

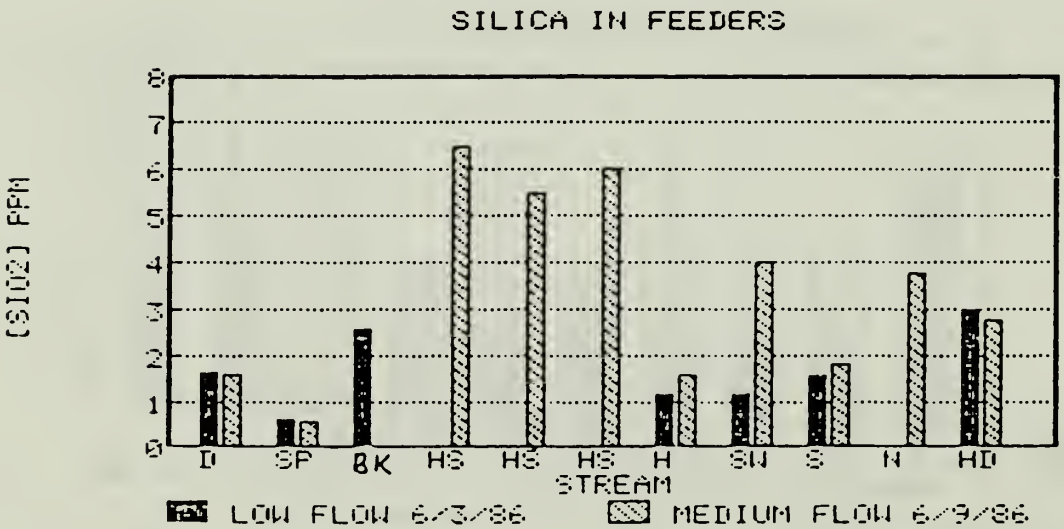


Figure 25

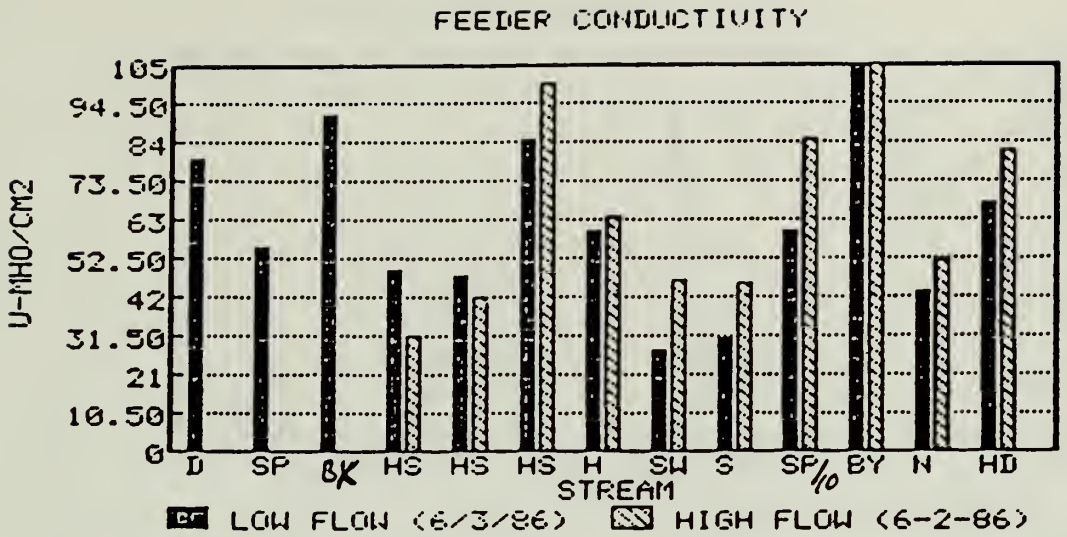


Figure 26

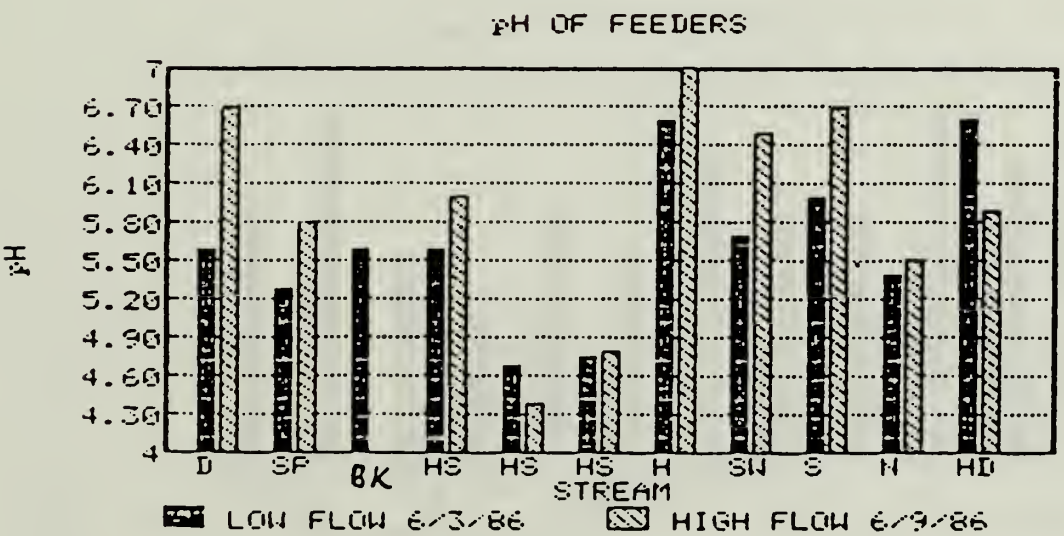


Figure 27

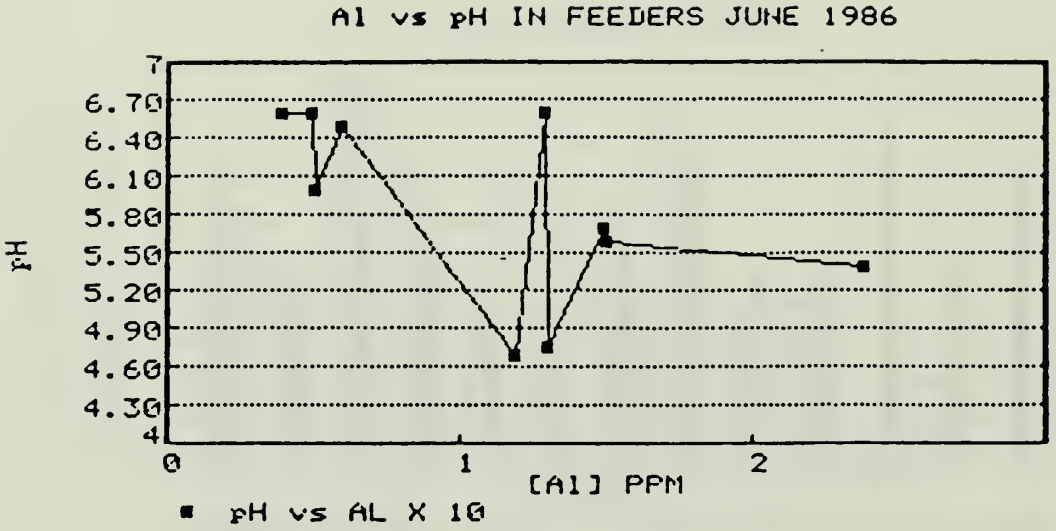


Figure 28

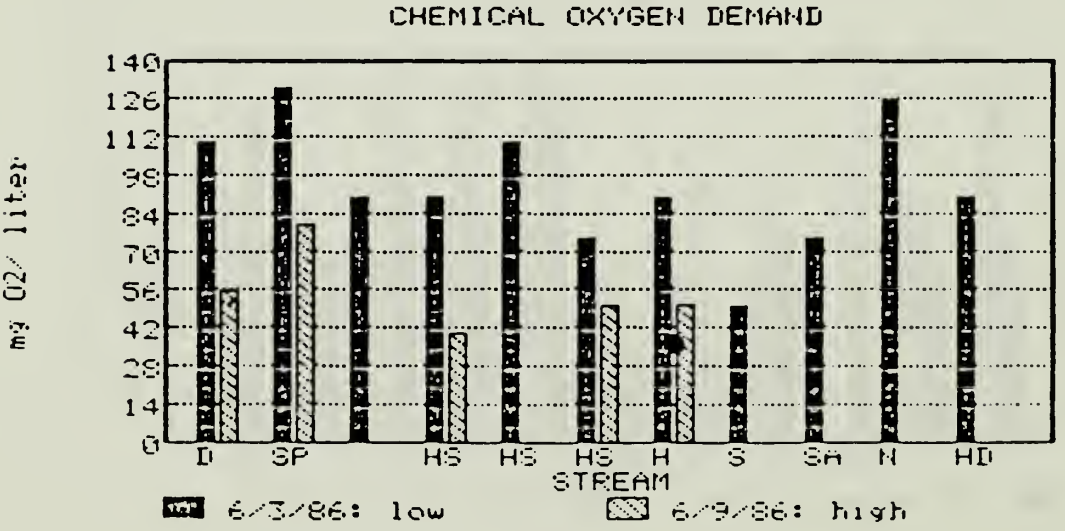


Figure 29

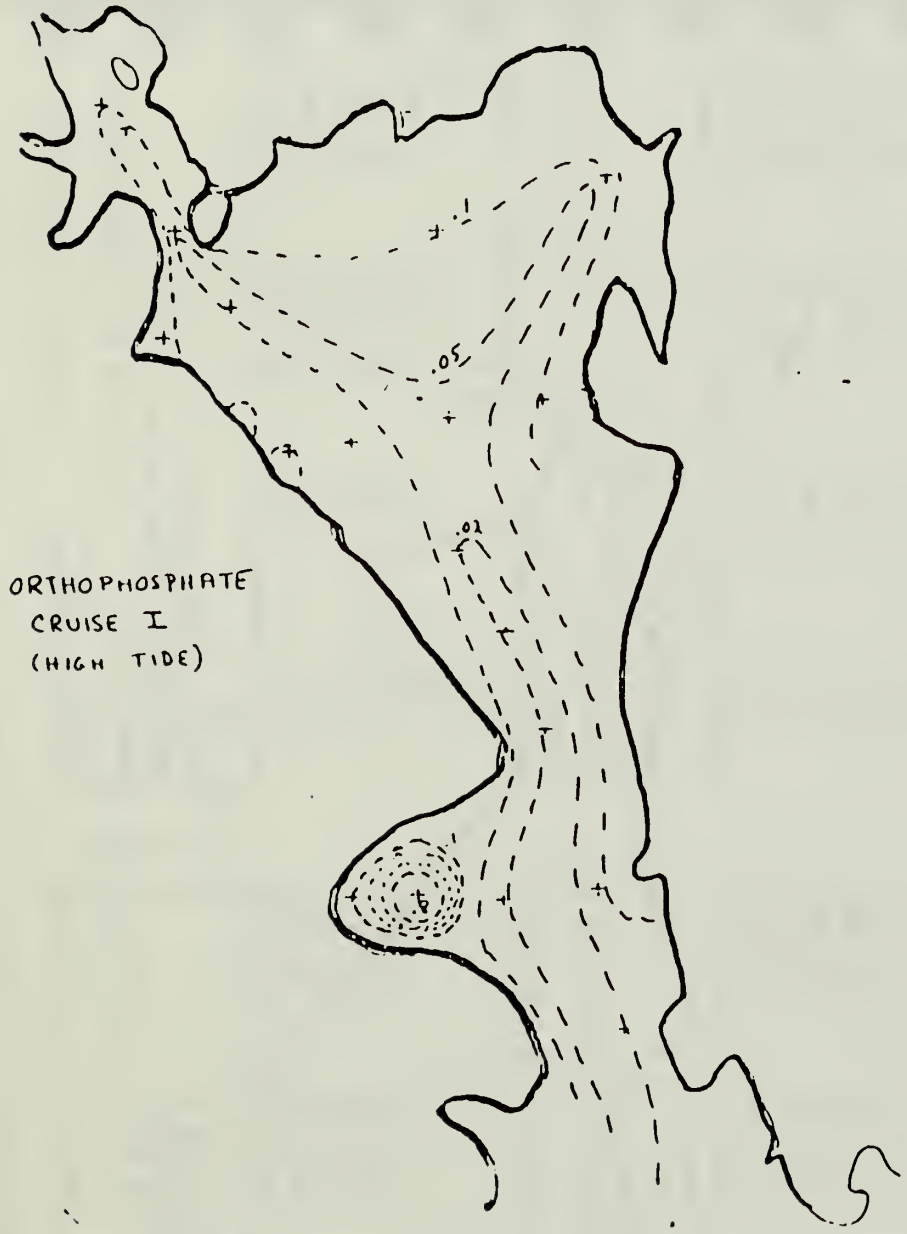


Figure 30 a.

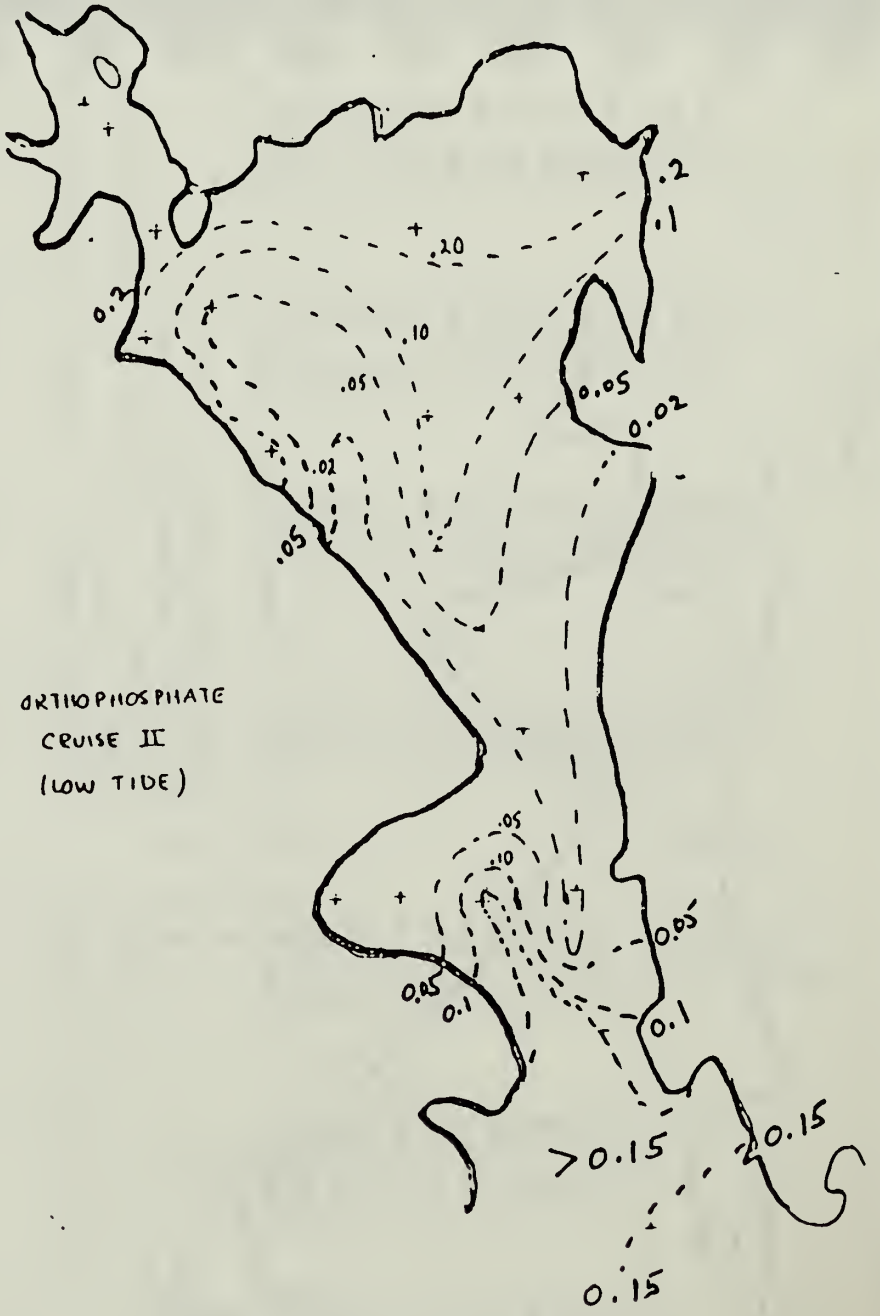
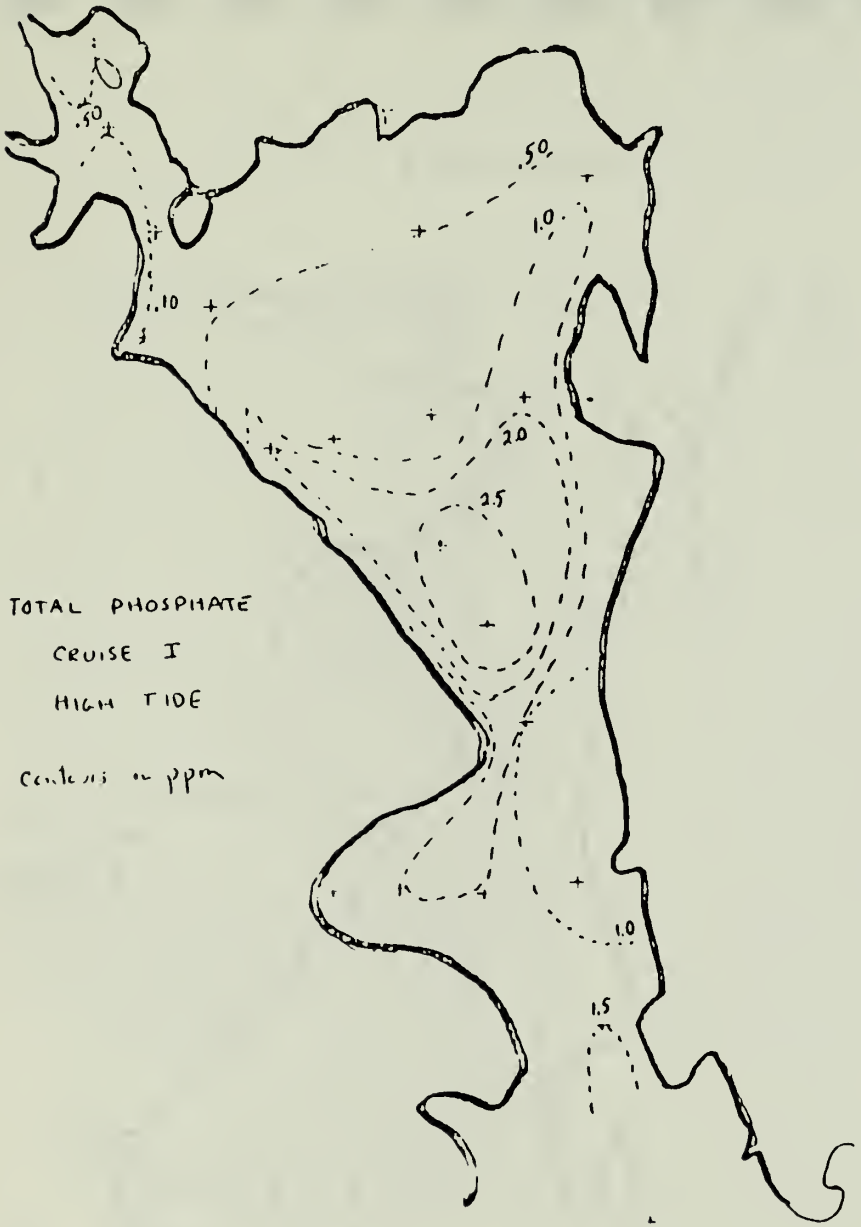


Figure 30 b.


TOTAL PHOSPHATE
CRUISE I
HIGH TIDE
Contours in ppm
.50
1.0
.10
2.0
2.5
1.0
1.5

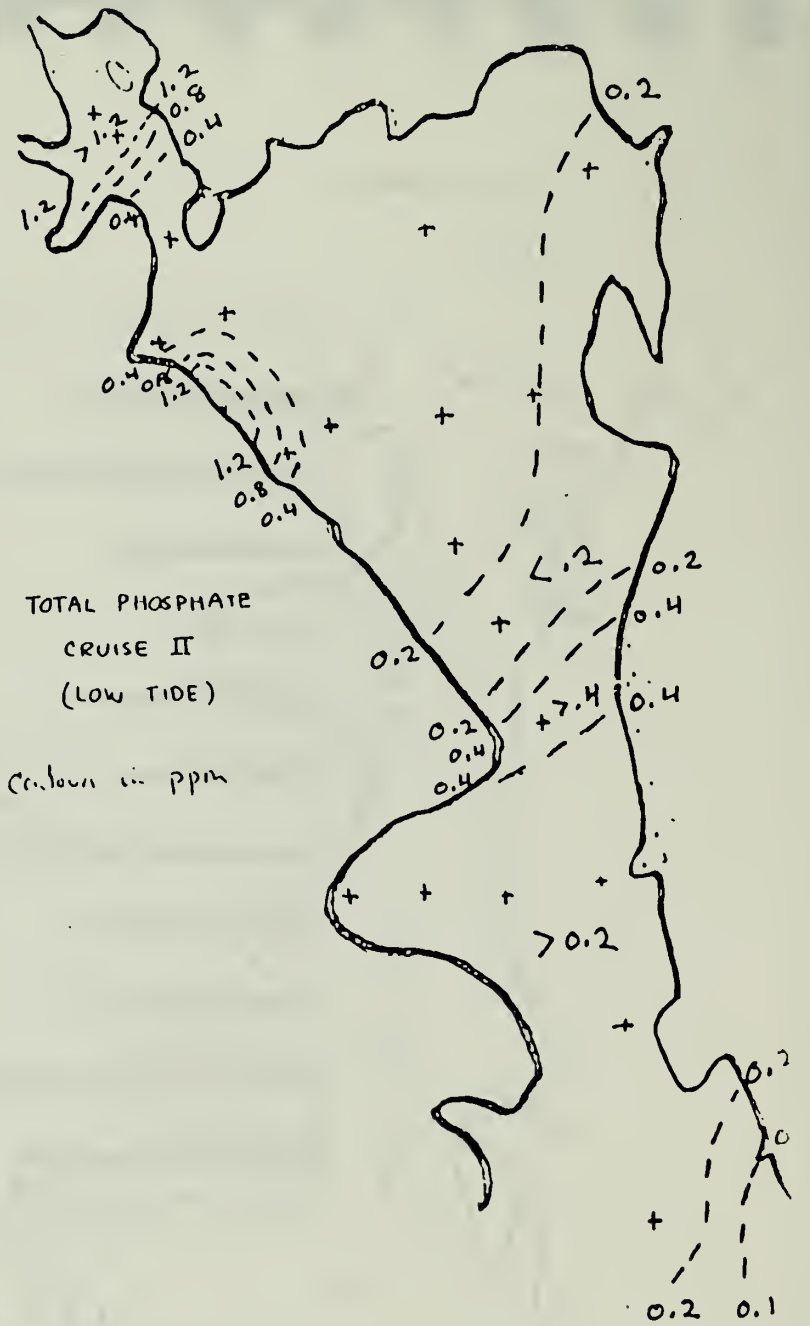

TOTAL PHOSPHATE
CRUISE II
(LOW TIDE)
Contours in ppm
1.2
0.8
0.4
0.2
0.1
0

Figure 31 b.

Somes Sound Cruise 1 April 15, 1986

Data: Time High 15:04 Time Low 9:01 Range 2.5 meters

on Number 1 Depth 5.5 meters
12:50
ion : 44 21.78 N 68 19.69 W
ce Temperature 9.7
Disk Depth 3.0 m

Temperature	Salinity	Sigma-t
7.39	29.23	22.82
5.09	30.73	24.29
4.70	30.78	24.37
4.62	30.82	24.41

Station Number 2 Depth 9.4 meters
Time 13:00
Position : 44 21.68 N 68 19.64 W
Surface Temperature 7.9
Sechi Disk Depth 3.4 m

Depth	Temperature	Salinity	Sigma-t
0.0	7.12	29.37	22.97
2.0	5.70	30.43	23.98
4.0	4.10	31.20	24.75
6.0	4.05	31.12	24.69
7.9	4.11	31.06	24.64

on Number 3 Depth 8.2 meters
13:14
ion : 44 21.27 N 68 19.54 W
ce Temperature 7.9

Temperature	Salinity	Sigma-t
7.20	29.85	23.34
6.93	30.26	23.69
4.25	31.08	24.64
3.91	31.31	24.86
3.85	31.31	24.86

Station Number 4 Depth 20.7 meters
Time 13:25
Position : 44 20.97 N 68 19.42 W
Surface Temperature 7.0
Sechi Disk Depth 3.7 m

Depth	Temperature	Salinity	Sigma-t
0.0	7.05	29.92	23.42
2.0	5.42	30.83	24.32
4.0	4.00	31.40	24.92
5.9	3.90	31.31	24.86
8.0	3.80	31.29	24.86
10.0	3.70	31.33	24.90
12.0	3.57	31.37	24.94
15.0	3.51	31.39	24.96
19.0	3.68	31.23	24.82

on Number 5 Depth 25.6 meters
13:43
tion : 44 20.44 N 68 19.53 W
ace Temperature 7.1
Disk Depth 16.0 m

Temperature	Salinity	Sigma-t
6.92	30.04	23.52
5.45	30.52	24.08
4.32	31.23	24.76
3.82	31.48	25.00
4.10	31.30	24.84
3.87	31.43	24.96
3.81	31.34	24.90
3.61	31.45	25.00
3.56	31.42	24.98
3.51	31.38	24.95

Station Number 6 Depth 47.5 meters
Time 14:30
Position : 44 20.00 N 68 18.93 W
Surface Temperature 6.5
Sechi Disk Depth 4.6 m

Depth	Temperature	Salinity	Sigma-t
0.0	6.70	30.07	23.57
2.0	5.62	30.68	24.18
4.0	4.67	31.09	24.61
6.0	4.16	31.36	24.88
8.0	4.16	31.30	24.83
10.0	3.87	31.38	24.92
12.0	3.80	31.35	24.90
15.0	3.67	31.39	24.95
20.0	3.65	31.39	24.94
25.0	3.47	31.56	25.10
30.0	3.47	31.55	25.09
35.0	3.57	31.47	25.02
40.0	3.57	31.43	24.99
42.0	3.58	31.43	24.99

Station Number 7 Depth 38.4 meters
Time 15:12
Position : 44 19.68 N 68 18.83 W
Surface Temperature 6.0

Depth	Temperature	Salinity	Sigma-t
0.0	6.38	30.30	23.79
2.0	5.08	30.90	24.42
4.0	4.35	31.29	24.80
6.0	4.16	31.39	24.90
8.0	4.15	31.41	24.91
10.0	3.95	31.53	25.03
12.0	3.94	31.49	25.00
15.0	3.92	31.49	25.01
20.0	3.88	31.38	24.92
25.0	3.77	31.52	25.04
30.0	3.76	31.53	25.05
35.0	3.66	31.38	24.94
40.0	3.63	31.38	24.94

Station Number 8 Depth 45.7 meters
Time 15:42
Position : 44 19.29 N 68 18.75 W
Surface Temperature 7.0

Depth	Temperature	Salinity	Sigma-t
0.0	7.08	30.07	23.53
2.0	5.20	30.78	24.31
4.0	4.48	31.25	24.75
6.0	4.29	31.29	24.80
8.0	4.16	31.48	24.97
10.0	4.16	31.43	24.93
12.0	4.16	31.42	24.92
15.0	4.12	31.47	24.96
20.0	4.04	31.51	25.00
25.0	4.04	31.47	24.97
29.5	3.90	31.31	24.86
35.0	3.86	31.48	25.00
40.0	3.80	31.40	24.94

Station Number 9 Depth 46.6 meters
Time 16:20
Position : 44 18.61 N 68 18.84 W
Surface Temperature 6.5

Depth	Temperature	Salinity	Sigma-t
0.0	6.30	30.31	23.81
2.0	5.31	30.97	24.45
4.0	4.67	31.26	24.75
6.0	4.66	31.37	24.84
8.0	4.59	31.36	24.83
10.0	4.33	31.50	24.97
12.0	4.32	31.44	24.92
15.0	4.24	31.52	24.99
20.0	4.18	31.52	25.00
25.0	3.99	31.69	25.16
30.0	3.99	31.65	25.13
35.0	3.92	31.73	25.19
40.0	3.92	31.69	25.16

Station Number 10 Depth 11.0 meters
Time 16:51
Position : 44 18.08 N 68 18.59 W
Surface Temperature 5.8
Sechi Disk Depth 3.4 m

Depth	Temperature	Salinity	Sigma-t
0.0	5.75	30.68	24.17
2.0	5.10	31.17	24.63
4.0	4.86	31.34	24.79
6.0	4.57	31.32	24.81
8.0	4.33	31.60	25.05
10.0	4.25	31.48	24.97

Somes Sound Cruise 1 April 15, 1986 (Cont.)

tion Number 11 Depth 21.9 meters
e 16:51
ition : 44 17.29 N 68 18.49 W
face Temperature 6.1
hi Disk Depth 4.6 m

th	Temperature	Salinity	Sigma-t
.0	5.81	30.86	24.31
.0	5.53	31.11	24.53
.0	5.07	31.31	24.74
.0	4.84	31.41	24.85
.0	4.35	31.53	24.99
.0	4.31	31.63	25.07
.0	3.76	31.85	25.31
.0	3.86	31.71	25.18
.0	3.77	31.75	25.23
.0	3.74	31.73	25.21

Station Number 12 Depth 6.1 meters
Time 10:19
Position : 44 18.65 N 68 18.64 W
Surface Temperature 6.5
Sechi Disk Depth 4.6 m

Depth	Temperature	Salinity	Sigma-t
0.0	5.59	30.26	23.85
2.0	5.29	30.54	24.11
4.0	5.12	30.69	24.25
5.5	4.21	31.50	24.98

tion Number 13 Depth 23.8 meters
e 9:54
ition : 44 18.63 N 68 19.02 W
face Temperature 6.1
hi Disk Depth 6.7 m

th	Temperature	Salinity	Sigma-t
.0	5.89	29.69	23.37
.0	5.58	30.19	23.80
.0	4.93	30.87	24.41
.0	4.37	31.29	24.80
.0	4.20	31.44	24.94
.0	4.12	31.53	25.01
.0	4.20	31.44	24.93
.0	4.22	31.39	24.90
.0	4.03	31.53	25.02
.0	4.10	31.50	25.00

Station Number 14 Depth 18.3 meters
Time 9:35
Position : 44 18.63 N 68 19.16 W
Surface Temperature 5.8

Depth	Temperature	Salinity	Sigma-t
0.0	6.48	29.18	22.90
2.0	5.68	29.94	23.59
4.0	5.59	30.09	23.72
6.0	4.55	30.97	24.53
8.0	4.37	31.20	24.73
10.0	4.47	31.10	24.64
12.0	4.32	31.25	24.78
14.0	4.22	31.31	24.83

tion Number 15 Depth 25.6 meters
e 10:44
ition : 44 20.40 N 68 19.29 W
face Temperature 8.5
hi Disk Depth 5.2 m

th	Temperature	Salinity	Sigma-t
.0	7.49	27.94	21.81
.0	5.83	30.49	24.01
.0	4.58	30.97	24.52
.0	4.00	31.23	24.79
.0	3.91	31.26	24.82
.0	3.87	31.32	24.87
.0	3.72	31.31	24.88
.8	3.47	31.44	25.01
.7	3.44	31.48	25.04
.6	3.44	31.42	24.99
.4	3.39	31.47	25.03

Station Number 16 Depth 18.3 meters
Time 11:05
Position : 44 20.53 N 68 18.95 W
Surface Temperature 7.3
Sechi Disk Depth 5.8 m

Depth	Temperature	Salinity	Sigma-t
0.0	6.38	30.30	23.79
2.0	5.18	30.84	24.36
4.0	4.73	30.96	24.51
6.0	4.32	31.12	24.67
8.0	4.05	31.35	24.88
10.0	3.98	31.37	24.90
12.0	3.89	31.43	24.96
14.8	3.77	31.38	24.93
16.5	3.74	31.41	24.95

Station Number 17 Depth 11.1 meters
Time 11:19
Position : 44 20.59 N 68 18.75 W
Surface Temperature 7.0
Sechi Disk Depth 5.2 m

Depth	Temperature	Salinity	Sigma-t
0.0	6.13	30.90	24.30
2.0	6.10	30.89	24.29
4.0	4.54	31.24	24.74
6.0	4.18	31.27	24.81
8.0	4.06	31.25	24.80
10.0	3.85	31.34	24.89

Station Number 18 Depth 10.7 meters
Time 11:33
Position : 44 20.85 N 68 19.57 W
Surface Temperature 9.2
Sechi Disk Depth 5.2 m

Depth	Temperature	Salinity	Sigma-t
0.0	6.80	28.94	22.67
2.0	5.53	30.54	24.08
4.0	4.32	30.93	24.52
6.0	4.10	31.12	24.69
8.0	3.96	31.07	24.67
9.5	3.95	31.02	24.63

Station Number 19 Depth 18.9 meters
Time 11:47
Position : 44 21.26 N 68 18.97 W
Surface Temperature 7.2
Sechi Disk Depth 5.5 m

Depth	Temperature	Salinity	Sigma-t
0.0	7.17	29.99	23.46
2.0	4.80	30.89	24.44
4.0	4.47	31.01	24.57
6.0	4.10	31.16	24.72
8.0	4.00	31.14	24.72
10.0	3.76	31.32	24.88
12.0	3.72	31.31	24.88
15.0	3.58	31.37	24.94
18.8	3.53	31.37	24.94

Station Number 20 Depth 4.9 meters
Time 12:05
Position : 44 21.47 N 68 18.61 W
Surface Temperature 7.9
Sechi Disk Depth 5.9 m

Depth	Temperature	Salinity	Sigma-t
0.0	5.62	30.93	24.38
2.0	4.44	31.11	24.65
4.0	3.98	31.23	24.79
5.0	3.98	31.23	24.79

Table 2

Somes Sound Cruise 2 April 19, 1986

Data: Time High 18:42 Time Low 12:34 Range 2.6 meters

on Number 1 Depth 2.7 meters
11:55
ion : 44 21.78 N 68 19.69 W
ce Temperature 7.5

Temperature	Salinity	Sigma-t
7.15	30.55	23.90
7.08	30.61	23.95

Station Number 2 Depth 7.0 meters
Time 12:04
Position : 44 21.68 N 68 19.64 W
Surface Temperature 7.9

Depth	Temperature	Salinity	Sigma-t
0.0	7.40	30.24	23.62
2.0	7.00	30.36	23.76
4.0	5.79	30.91	24.35
5.5	5.62	30.87	24.33

on Number 3 Depth 7.0 meters
12:11
ion : 44 21.27 N 68 19.54 W
ce Temperature 8.6

Temperature	Salinity	Sigma-t
7.08	29.95	23.44
6.44	30.65	24.06
5.36	31.21	24.63

Station Number 4 Depth 14.6 meters
Time 12:17
Position : 44 20.97 N 68 19.42 W
Surface Temperature 6.7
Sechi Disk Depth 4.0 m

Depth	Temperature	Salinity	Sigma-t
0.0	6.83	29.44	23.07
2.0	5.66	30.88	24.34
4.0	5.10	31.23	24.67
6.0	4.65	31.22	24.72
8.0	4.42	31.35	24.84
9.7	4.36	31.34	24.84
14.8	3.60	31.46	25.01

on Number 5 Depth 21.9 meters
12:38
ion : 44 20.44 N 68 19.15 W
ce Temperature 6.0

Temperature	Salinity	Sigma-t
5.80	31.03	24.44
5.63	31.11	24.52
5.24	31.02	24.49
4.86	31.34	24.79
4.86	31.35	24.79
4.44	31.20	24.72
3.99	31.30	24.84
3.74	31.38	24.93
3.68	31.32	24.89

Station Number 6 Depth 38.4 meters
Time 12:56
Position : 44 20.00 N 68 18.93 W
Surface Temperature 6.0

Depth	Temperature	Salinity	Sigma-t
0.0	6.07	30.89	24.30
2.0	6.00	30.96	24.36
4.0	5.55	31.08	24.51
5.9	5.31	31.20	24.63
8.0	5.13	31.18	24.64
10.0	4.59	31.39	24.86
15.0	4.03	31.60	25.08
19.6	3.89	31.44	24.96
25.0	3.80	31.51	25.03
29.5	3.72	31.48	25.01
35.0	3.70	31.50	25.03
40.0	3.70	31.47	25.01

Table 2 (cont)

Somes Sound Cruise 2 April 19, 1986 (Cont.)

Station Number 7 Depth 31.1 meters
Time 13:45
Position : 44 19.68 N 68 18.83 W
Surface Temperature 6.0

Depth	Temperature	Salinity	Sigma-t
0.0	6.20	30.67	24.11
2.0	5.92	30.75	24.21
4.0	5.96	30.85	24.28
6.0	5.75	30.85	24.30
8.0	5.43	31.01	24.46
10.0	4.77	31.17	24.66
15.0	4.20	31.20	24.75
20.0	4.10	31.27	24.81
25.0	4.16	31.05	24.63
29.0	4.38	30.75	24.37

Station Number 8 Depth 45.7 meters
Time 14:27
Position : 44 19.29 N 68 18.75 W
Surface Temperature 6.3

Depth	Temperature	Salinity	Sigma-t
0.0	6.26	30.83	24.23
2.0	5.90	30.94	24.36
4.0	5.78	30.99	24.41
6.0	5.43	31.33	24.72
8.0	5.06	31.49	24.89
10.0	5.06	31.43	24.84
12.0	4.94	31.43	24.85
15.0	4.63	31.48	24.92
20.0	4.41	31.49	24.95
25.0	4.19	31.48	24.97
30.0	4.12	31.53	25.01
35.0	4.12	31.50	24.99
40.0	4.12	31.49	24.98

Station Number 9 Depth 45.7 meters
Time 15:00
Position : 44 18.61 N 68 18.84 W
Surface Temperature 6.0

Depth	Temperature	Salinity	Sigma-t
0.0	5.89	31.08	24.47
2.0	5.94	31.07	24.45
4.0	5.82	31.04	24.45
6.0	5.73	31.17	24.56
8.0	5.68	31.20	24.59
10.0	5.53	31.31	24.69
12.0	5.54	31.34	24.72
15.0	5.42	31.27	24.68
19.7	5.10	31.37	24.78
24.6	4.88	31.50	24.92
29.5	4.82	31.50	24.92
34.5	4.72	31.35	24.81
39.4	4.58	31.36	24.84

Station Number 10 Depth 17.1 meters
Time 15:25
Position : 44 18.08 N 68 18.59 W
Surface Temperature 5.9

Depth	Temperature	Salinity	Sigma-t
0.0	5.83	31.35	24.69
2.0	5.70	31.40	24.75
4.0	5.70	31.40	24.75
6.0	5.70	31.42	24.76
8.0	5.38	31.45	24.82
10.0	5.26	31.58	24.94
15.0	5.22	31.56	24.93

Table 2 (cont)

Somes Sound Cruise 2 April 19, 1986 (Cont.)

n Number 11 Depth 21.9 meters
15:42
on : 44 17.29 N 68 18.49 W
e Temperature 5.9

Temperature	Salinity	Sigma-t
5.68	31.41	24.75
5.65	31.45	24.79
5.50	31.48	24.83
5.10	31.68	25.03
5.21	31.63	24.98
5.20	31.66	25.01
5.20	31.58	24.95
4.98	31.79	25.13
4.97	31.72	25.08

Station Number 15 Depth 25.6 meters
Time 10:00
Position : 44 20.40 N 68 19.29 W
Surface Temperature 5.5

Depth	Temperature	Salinity	Sigma-t
0.0	5.44	31.24	24.65
2.0	5.40	31.28	24.68
4.0	5.22	31.30	24.72
6.0	5.22	31.33	24.74
8.0	4.70	31.36	24.82
10.0	4.55	31.40	24.87
12.0	4.27	31.51	24.99
15.0	4.24	31.59	25.05
19.7	4.05	31.57	25.05
21.6	3.69	31.50	25.03

on Number 18 Depth 10.4 meters
10:25
.on : 44 20.85 N 68 19.57 W
te Temperature 5.8

Temperature	Salinity	Sigma-t
5.78	30.51	24.03
5.76	30.62	24.12
5.22	31.40	24.80
4.85	31.54	24.95
4.77	31.50	24.93
4.71	31.36	24.82

Station Number 20 Depth 5.2 meters
Time 10:43
Position : 44 21.47 N 68 18.61 W
Surface Temperature 4.5

Depth	Temperature	Salinity	Sigma-t
0.0	4.45	31.23	24.74
2.0	4.04	31.69	25.15
3.5	3.78	31.78	25.24

Table 3

Stream Flow Field Measurements
1986

Stream	Date	Method	Flow Rate (cfs)
Hadlock Brook	29-Mar	Float	19.78
Hadlock Brook	12-Apr	Float	11.05
Southwest Valley Brook	29-Mar	Float	4.67
Southwest Valley Brook	12-Apr	Float	3.48
Southwest Valley Brook	12-Apr	Meter	2.71
Sargent Brook	29-Mar	Float	6.41
Sargent Brook	02-Apr	Float	2.11
Sargent Brook	02-Apr	Meter	1.78
Sargent Brook	12-Apr	Float	2.26
Sargent Brook	12-Apr	Meter	2.52
Richardson Brook	02-Apr	Meter	12.04
Babson Creek	02-Apr	Meter	3.55
Somes Pond Outflow	02-Apr	Meter	29.45
Denning Brook	29-Mar	Float	27.18
Denning Brook	12-Apr	Float	16.87
Denning Brook	12-Apr	Meter	15.94

Table 4

Somes Sound Drainage Areas

Number of days	7	8	14	21	28	Days
Average Rain Fall	0.17	0.19	0.11	0.12	0.14	Inches/day
Run-off	50.0%	50.0%	50.0%	50.0%	50.0%	

Map qion	Streams	Drainage Area Sq Mi	Flow Rates (Cfs)	(Cfs)	(Cfs)	(Cfs)	(Cfs)
3	Man-o-war	0.304	0.70	0.78	0.45	0.49	0.57
2	Denning	2.883	6.59	7.36	4.26	4.65	5.43
9	Hadlock	2.067	4.72	5.28	3.06	3.33	3.89
6	Heath & Richardson	3.692	8.44	9.43	5.46	5.96	6.95
5	High School (3 streams)	0.729	1.67	1.86	1.08	1.18	1.37
4	Kitteridge & Babson	3.082	7.04	7.87	4.56	4.97	5.80
7	Sargent Brook-North	0.815	1.86	2.08	1.21	1.31	1.53
8	Sargent Brook-South	0.694	1.59	1.77	1.03	1.12	1.31
1	Somes Pond Outflow	8.640	19.75	22.07	12.78	13.94	16.26
	Direct Drainage						
10	Acadia Mt.- St. Sauveur	0.438	1.00	1.12	0.65	0.71	0.82
15	Norumbega Mt.	1.745	3.99	4.46	2.58	2.82	3.28
14	Near Richardson brook	0.143	0.33	0.37	0.21	0.23	0.27
11	Hall Quary	1.199	2.74	3.06	1.77	1.93	2.26
13	Sheep Is. & Point	0.326	0.75	0.83	0.48	0.53	0.61
12	Somesville	0.898	2.05	2.29	1.33	1.45	1.69
16	Somes Sound Proper	2.915	6.66	7.45	4.31	4.70	5.49
			Totals in Cubic Feet Per Second				
	Total Stream	22.906	52.35	58.51	33.88	36.96	43.11
	Total Direct (w/o sound)	4.749	10.85	12.13	7.02	7.66	8.94
	Total Sound Proper	2.915	6.66	7.45	4.31	4.70	5.49

Table 5

Calculation of Runoff Percentage
Data of April 12, 1986

Average Rain Fall 0.26
Run-off percentage 100.0%

Streams	Drainage Area Sq Mi	(Cfs)	Observed Flow Rates (Cfs)	Calculated Runoff Percentage (Cfs)
Denning	2.883	19.89	16.40	82.4%
Hadlock	2.067	14.26	11.05	77.5%
Southwest Valley	0.815	5.62	3.09	54.9%
Sargent Brook	0.694	4.79	2.39	49.9%
			Average	66.2%

Table 6

Soaes Sound Daily Drainage

Number of days prior to April 15	5	6	7	8	9	10
Daily Rain Fall	0.00	0.55	0.42	0.32	0.00	0.00
Run-off percentage	66.0%	66.0%	66.0%	66.0%	66.0%	66.0%

		Drainage Area	Calculated Flow Rates					
ap	Streams							
on		Sq Mi	(Cfs)	(Cfs)	(Cfs)	(Cfs)	(Cfs)	(Cfs)
3	Man-o-war	0.304	0.00	2.97	2.27	1.73	0.00	0.00
2	Denning	2.883	0.00	28.14	21.49	16.37	0.00	0.00
9	Hadlock	2.067	0.00	20.17	15.41	11.74	0.00	0.00
6	Heath & Richardson	3.692	0.00	36.03	27.52	20.97	0.00	0.00
5	High School (3 streams)	0.729	0.00	7.11	5.43	4.14	0.00	0.00
4	Kittredge & Babson	3.082	0.00	30.09	22.97	17.50	0.00	0.00
7	Southwest Valley	0.815	0.00	7.95	6.07	4.63	0.00	0.00
8	Sargent Brook	0.694	0.00	6.78	5.18	3.94	0.00	0.00
1	Soaes Pond Outflow	8.640	0.00	84.33	64.40	49.07	0.00	0.00
	Direct Drainage							
0	Acadia Mt.- St. Sauveur	0.438	0.00	4.27	3.26	2.48	0.00	0.00
5	Norumbega Mt.	1.745	0.00	17.03	13.01	9.91	0.00	0.00
4	Near Richardson brook	0.143	0.00	1.40	1.07	0.81	0.00	0.00
1	Hall Quary	1.199	0.00	11.71	8.94	6.81	0.00	0.00
3	Sheep Is. & Point	0.326	0.00	3.18	2.43	1.85	0.00	0.00
2	Soaesville	0.898	0.00	8.76	6.69	5.10	0.00	0.00
6	Soaes Sound Proper	2.915	0.00	28.45	21.73	16.55	0.00	0.00
			Totals in Cubic Feet Per Second					
		Areas						
	Total Streas	22.906	0.00	223.58	170.73	130.08	0.00	0.00
	Total Direct (w/o sound)	4.749	0.00	46.36	35.40	26.97	0.00	0.00
	Total Sound Proper	2.915	0.00	28.45	21.73	16.55	0.00	0.00
			Total Converted to cubic aeters per day (* 10^6)					
	Daily inflow -- Streaas		0.000	0.547	0.418	0.316	0.000	0.000
	Daily inflow -- Direct		0.000	0.113	0.087	0.066	0.000	0.000
	Daily inflow -- Sound		0.000	0.070	0.053	0.041	0.000	0.000
	Volume of fresh water in the sound (April 15, 1986, *10^6 m^3)		1.782	1.782	1.782	1.782	1.782	1.782
			Total fresh water accumulation from runoff					
	Accumulated Total Inflow Streams, Direct & Sound		0.332	1.062	1.619	2.044	2.044	2.044

Table 7

	Date	Flow	Phosphate [PO4] (ppm)	[T-PO4] (ppm)	Nitrate [NO3] (ppm)	[NH3] (ppm)		[SiO2] (ppm)	[AL] (ppm)	[Fe] (ppm)	[pH]	COD	Conduct-tivity (umho/cm)
Test Range:			0-3	0-3	0-130	0-3		0-3	0-1				
Hall Quarry	6/3	Medium	2.50		7.97	0.58			0.03		6.10		900
Hall Quarry	6/10	Lowest	0.40		2.21	0.45	>	3.00	0.07				
Denning Brook	6/3	Medium	4.20	12.00	9.30	0.26		1.90		0.15	5.60	110	80
								1.60					
Denning Brook	6/9	Medium	0.05	0.50	3.98	0.32		1.60			6.70	55	
Denning Brook	6/10	Lowest	0.05		2.21	0.32		1.50					
Somes Pond Brook	6/3	Medium	5.00	8.00	9.30	0.57		0.70		0.15	5.30	130	56
Somes Pond Brook	6/9	Medium	0.02	0.50	3.98	0.32		0.61			5.80	80	
Babson & Kitteridge	6/3	Medium	0.60	8.80	3.54	0.61		2.60		0.18	5.60	90	92
			0.80										
Babson & Kitteridge	6/10	Lowest	0.05		2.21	0.84	>	3.00					
High School-West	6/2	Highest		3.90	6.64	2.06		9.20	0.15				32
				3.50					0.16				
High School-West	6/3	Medium	4.80		8.41	0.54	>	4.00		0.21	5.60	90	50
			5.30		7.53	0.60							
High School-West	6/9	Medium	1.70	1.85	2.21	0.71		6.50			6.00	40	
High School-Central	6/2	Highest		2.70	17.49	1.93		3.50	0.13				42
				2.80					0.10				
High School-Central	6/3	Medium	2.80	8.50	4.43	1.03	>	4.00		0.18	4.70	110	48
High School-Central	6/9	Medium	2.40		9.74	1.03		5.50		4.40			
High School-East	6/2	Highest		2.90	14.39	2.83		3.40	0.14				100
				3.20					0.12				
High School-East	6/5	Medium	> 3.00	6.00	4.43	1.05	>	4.00		0.18	4.75	75	85
High School-East	6/9	Medium	2.10	2.50	9.74	1.03		6.00			4.80		
Heath & Richardson	6/2	Highest		> 4.00	6.64	1.41		2.20	0.05				64
Heath & Richardson	6/3	Medium	4.70		4.87	0.32		1.20			6.60	90	60
Heath & Richardson	6/9	Medium	0.88	7.50	7.97	0.32		1.60			7.00	50	
Southwest Valley	6/2	Highest		> 4.00	5.31	1.41		8.80	0.16				47
									0.13				
Southwest Valley	6/3	Medium	2.20	6.00	2.21	0.45		1.20		0.24	5.70		28
Southwest Valley	6/9	Medium	7.00	7.00	8.85	0.39		4.00			6.50		
Sargent Brook	6/2	Highest		2.70	5.31	0.51		4.00	0.05				46
				2.00									
Sargent Brook	6/3	Medium	1.90	4.50	0.00	0.18		1.60		0.00	6.00	50	31
Sargent Brook	6/9	Medium	0.85	1.75	4.43	0.05		1.88			6.70		
Sand Pile	6/2	Highest			3.54	0.90		3.40	0.06				600
Sand Pile	6/3	Medium	3.00	5.00	2.21	0.51		1.50		0.32	6.50	75	850
Boatyard	6/2	Highest		1.90	3.98	0.77		8.20	0.04				105
				1.70					0.03				
Boatyard	6/3	Medium	> 3.00	0.50	8.85	0.28		2.40		0.05	6.60		105
Boatyard	6/9	Medium		12.00	6.64			1.80	9.00		6.30		
								1.60	5.60				
Norumbega	6/2	Highest		3.00	3.98	1.35			0.24				52
				3.10					0.24				
Norumbega	6/3	Medium	2.40	5.00	6.64	0.24				0.05	5.40	125	44
Norumbega	6/9	Medium	2.10	2.50	3.98	0.14		3.80			5.50		
Hadlock Brook	6/2	Highest			5.31	0.67		2.60	0.13				82
Hadlock Brook	6/3	Medium	7.95	8.50	4.87	0.18		3.00		0.09	6.60	90	68
Hadlock Brook	6/9	Medium	5.30	4.50	6.20	0.17		2.80			5.90		
Averages			2.66	4.42	5.94	0.72		3.25	0.83	0.48	5.93	84	153
Standard Deviation			2.09	2.96	3.40	0.59		2.13	2.22	1.14	0.64	27	244

Table 8

Comparison data for MDI and Hubbard Brook (NH)

	Nitrate [ppm]				Ammonia [ppm]			
	All Year		June		All Year		June	
	MDI	Hubbard Brook	MDI	Hubbard Brook	Hubbard Brook	MDI	Hubbard Brook	
FOG								
4 Range			3-33			2-19		
rage			10.33			6.62		
Dev.			9.18			5.90		
RAIN								
4 Range		1-2	0-7.5			.01-1		
Average		1.47	1.56	1.4	.19	1.53	.23	
Std. Dev.			1.96			4.12		
NP Streams								
3 Range		.02-3	0	.02-.06				
Average	.25	1.73	0	.04	.027	Not done	.02	
Feeding into Somes Sound (June 1986)								
Range			0-17.4			0.05-2.8		
Average			5.94			0.72		
Std. Dev.			3.40			0.59		

Table 9 a.

Somes Sound Water Analysis

April 15, 1986 Cruise

Station	Phosphate Ortho [ppm]	Phosphate Total [ppm]	Sulfate Method 1 [ppm]	Sulfate Method 2 [ppm]	Chemi Oxygen Demand
1	0.09	0.55	1798	992	1612
2	0.09	0.08	1612	744	
3	0.05		1426	1401	1550
4	0.06	0.55	1922	1612	
5			2108	1364	
5a	0.07	1.80	1612	1612	
5b	0.08	0.47	1922	1798	
5c	0.15	0.60	1860	1674	
5d	0.02	0.35			
5e	0.02	0.17	1736	1798	
6	0.02	2.50	1612		
6-deep	0.02	0.15	1860		
7	0.02	2.80		1798	
7-deep	0.02	2.30		1798	
8	0.02	0.18	1860	2170	1240
8-deep	0.02	1.00			
9	0.02	0.85	1674		
9-deep	0.02	0.40	1922		
10	0.02	1.30	1922	1364	
12	0.05	0.05	1550		16430
13	0.88	0.90			
14	0.10	0.10			
15	0.15	0.87			
16	0.05	0.03	1984		
17	0.10	1.80	1984		
18	0.09	0.07	1612		
19	0.12	0.46			
20	0.05	1.00			11250
Average	0.09	0.82	1788	1548	
Deviation	0.16	0.79	177	362	

Table 9 b.

Somes Sound Water Analysis

April 19, 1986 Cruise

tation	Phosphate Ortho [ppm]	Phosphate Total [ppm]	Chemical Oxygen Demand
2	0.11	1.23	2420
3	0.20	0.21	3135
4	0.05	0.24	750
5	0.01	0.09	
6	0.12	0.25	5000
6-deep	0.20	1.40	10850
7	0.08	0.15	
8		0.80	8060
8-deep	0.10	0.77	4030
9	0.15	0.30	
9-deep	0.15	0.21	
10	0.15	0.32	600
10a	0.07	0.27	
11	0.12	0.32	
11-deep	0.07	0.12	
11a	0.16	0.25	
11b	0.10	0.15	5580
11c	0.13		
11d	0.12	0.10	
12	0.02	0.12	
15	0.12	0.35	
15a	0.10	0.27	
15c	0.08	1.50	
15d		1.20	
18	0.19	0.29	3100
20	0.16	0.15	
20-deep	0.13	0.60	
20a	0.08	0.22	
0a-deep	0.24	0.39	
Average	0.12	0.44	Cruise 2
eviation	0.05	0.41	

Table 10

Oxygen in Somes Sound
(in percent oxygen saturation)
(From Gilmartin 1986)

Station:	off SWH	off SWH	Valley Cove	N Valley Cove	S Hall Quarry	N Hall Quarry	North Sound
Year:	1981	1982	1981	1982	1982	1981	1982
depth(m)							
0	81	76	90	67	73	91	65
5	78					74	40
7.5				60	49		
10			79			64	
15		71		57	41	65	29
20	73	70	76			69	
25					40		
30			76				
40			75	41			
45			75				

Appendix A

Temperature, salinity and sigma-t -- August 13, 1986

The following figures and table report results on the temperature, salinity and sigma-t from a summer cruise on Somes Sound on August 13, 1986.

A.1 Figure legends for appendix -- A

Figure A-1 a-c. High tide along-the-sound section for the August 13 cruise. The location of the along-the-sound section is given in Figure 2a of the main report. a. Along-the-sound temperature section, d. Along-the-sound salinity section, c. Along-the-sound sigma-t (density) section. Somes Harbor is located at the far left of the section.

Figure 7(a-u). Vertical profiles for temperature (T), salinity (S) and sigma-t (*) for each station for the August 13, 1986 cruise. The location of each station is indicated in Figure 1 of the main report.

A.2 Table legend for appendix -- A

Table 1. Temperature, salinity and sigma-t data for the August 13, 1986 cruise in Somes Sound. The station locations are indicated in Figure 1 of the main report.

Table A-1.

Somes Sound Cruise 5 August 13, 1986

Tide Data: Time High 17:17 Time Low 10:05 Range 3.3 meters

Station Number 2 Depth 9.4 meters
Time 14:30
Position : 44 21.68 N 68 19.64 W
Surface Temperature 7.9
Sechi Disk Depth 4.0 m

Depth	Temperature	Salinity	Sigma-t
0.0	17.10	30.11	21.74
2.0	16.34	30.42	22.15
4.0	14.72	30.96	22.92
6.0	14.00	30.95	23.06
7.0	13.80	31.02	23.15

Station Number 4 Depth 16.5 meters
Time 15:07
Position : 44 20.97 N 68 19.42 W
Surface Temperature 16.0
Sechi Disk Depth 3.3 m

Depth	Temperature	Salinity	Sigma-t
0.0	15.96	30.64	22.41
2.0	15.06	31.08	22.94
4.0	14.04	31.10	23.17
5.9	13.58	31.27	23.39
10.0	12.94	31.31	23.55
13.0	12.76	31.27	23.55

Station Number 6 Depth 38.4 meters
Time 15:35
Position : 44 20.00 N 68 18.93 W
Surface Temperature 15.9
Sechi Disk Depth 3.3 m

Depth	Temperature	Salinity	Sigma-t
0.0	16.10	30.78	22.48
2.0	15.22	31.10	22.92
6.0	13.62	31.11	23.26
10.0	13.18	31.13	23.36
20.0	12.74	31.26	23.55
30.0	12.52	31.40	23.70
40.0	12.52	31.31	23.62

Station Number 8 Depth 47.5 meters
Time 16:06
Position : 44 19.29 N 68 18.75 W
Surface Temperature 15.7
Sechi Disk Depth 5.0 m

Depth	Temperature	Salinity	Sigma-t
0.0	14.76	31.23	23.12
2.0	13.58	31.24	23.37
6.0	13.24	31.36	23.53
10.0	13.02	31.36	23.57
20.0	12.76	31.45	23.69
40.0	12.38	31.46	23.77

Station Number 9 Depth 45.7 meters
Time 16:35
Position : 44 18.61 N 68 18.84 W
Surface Temperature 15.2

Depth	Temperature	Salinity	Sigma-t
0.0	14.88	31.06	22.97
2.0	14.00	31.15	23.22
6.0	13.49	31.28	23.42
10.0	13.53	31.26	23.40
20.0	13.48	31.29	23.43
30.0	13.36	31.26	23.42
40.0	13.11	31.29	23.50

Station Number 11 Depth 18.3 meters
Time 17:05
Position : 44 17.29 N 68 18.49 W
Surface Temperature 14.8
Sechi Disk Depth 4.0 m

Depth	Temperature	Salinity	Sigma-t
0.0	14.28	31.17	23.18
2.0	14.12	31.26	23.27
6.0	13.60	31.20	23.33
10.0	12.52	31.36	23.66
18.0	11.63	31.46	23.91

Somes Sound Cruise 5 August 13, 1986
Salinity

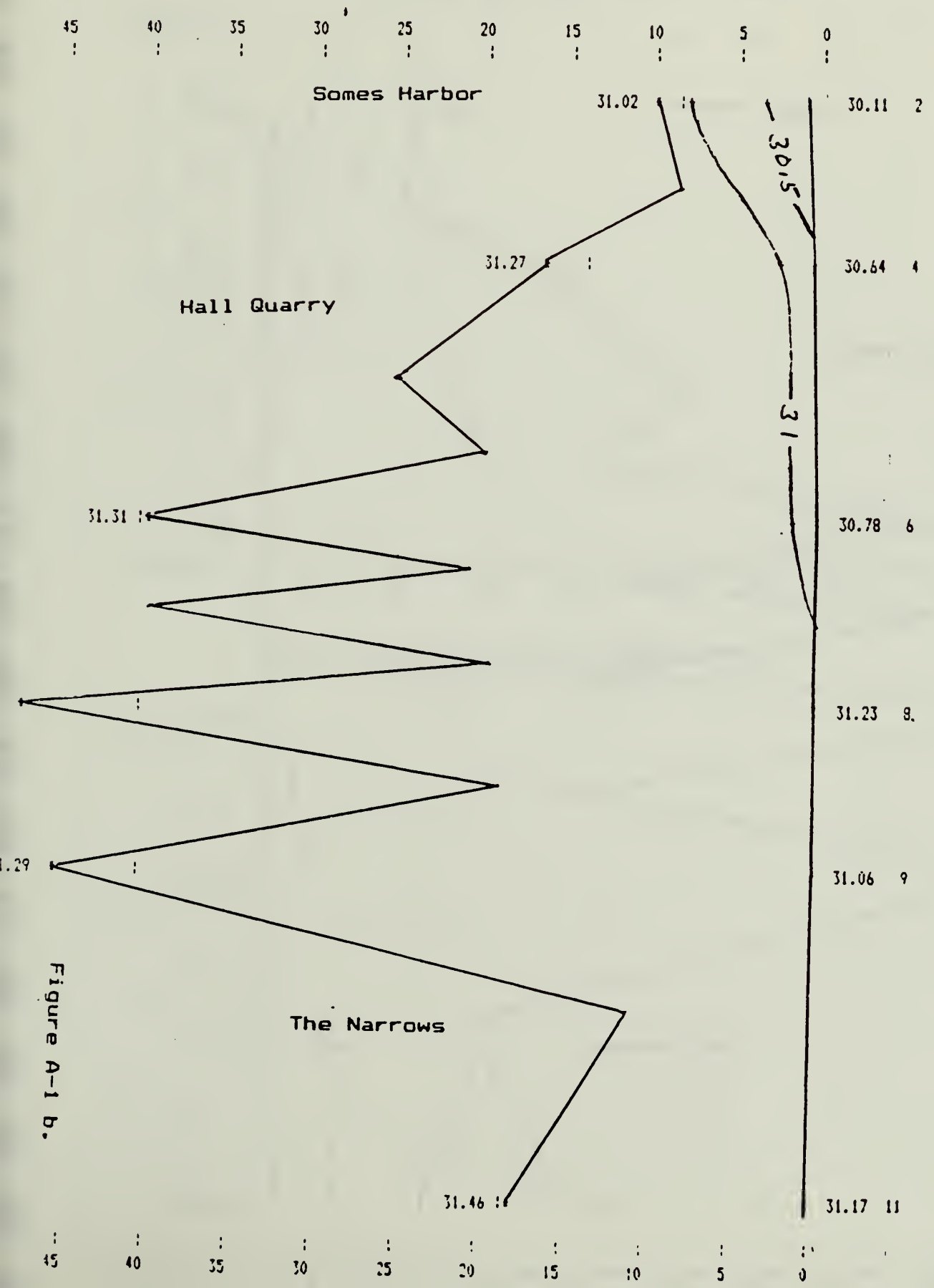


Figure A-1 b.

Somes Sound Cruise 5 August 13, 1986
Temperature

Base = 0.00 Interval = 1.0

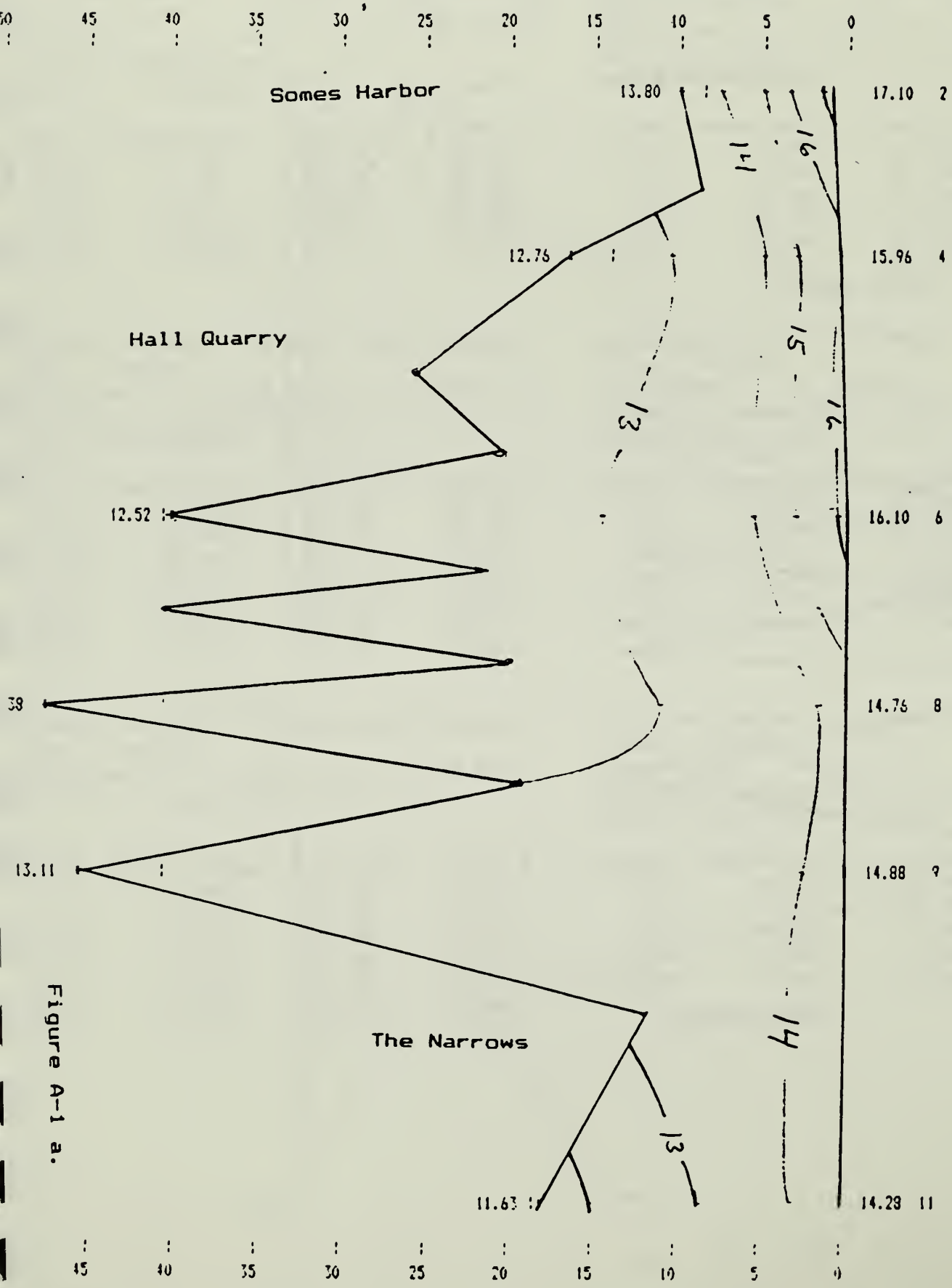


Figure A-1 a.

Somes Sound Cruise 5 August 13, 1986 Station # 2
44 21.7 N 68 19.6 W

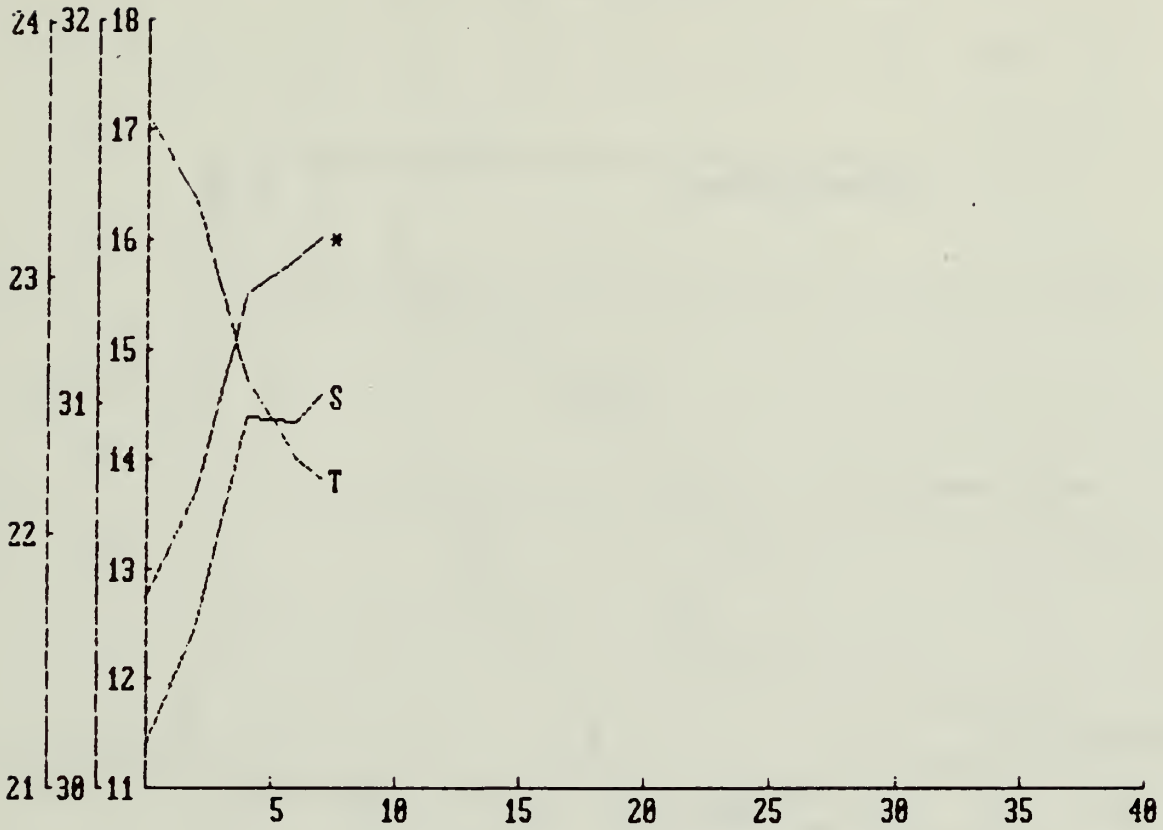
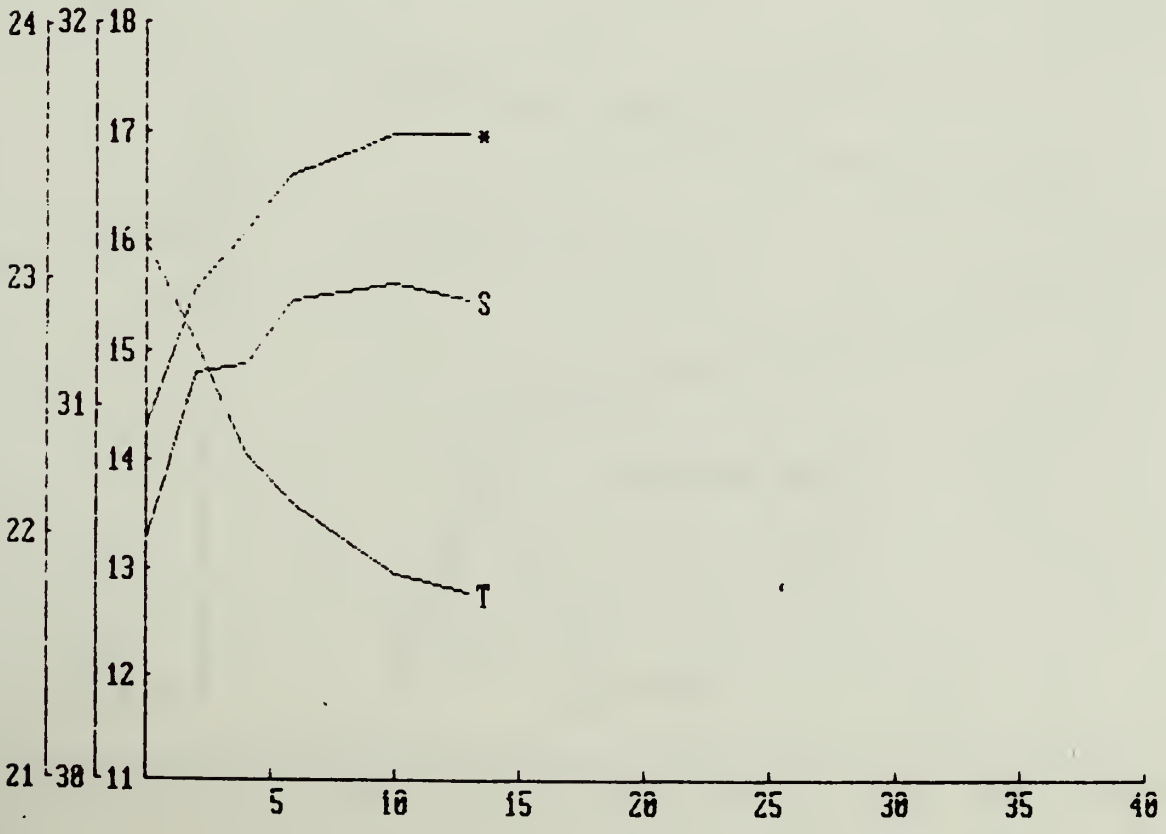


Figure A-2 a.

Somes Sound Cruise 5 August 13, 1986 Station # 4
44 21.0 N 68 19.4 W



Somes Sound Cruise 5 August 13, 198
Sigma-t

Base = 22.00 Interval = 0.5

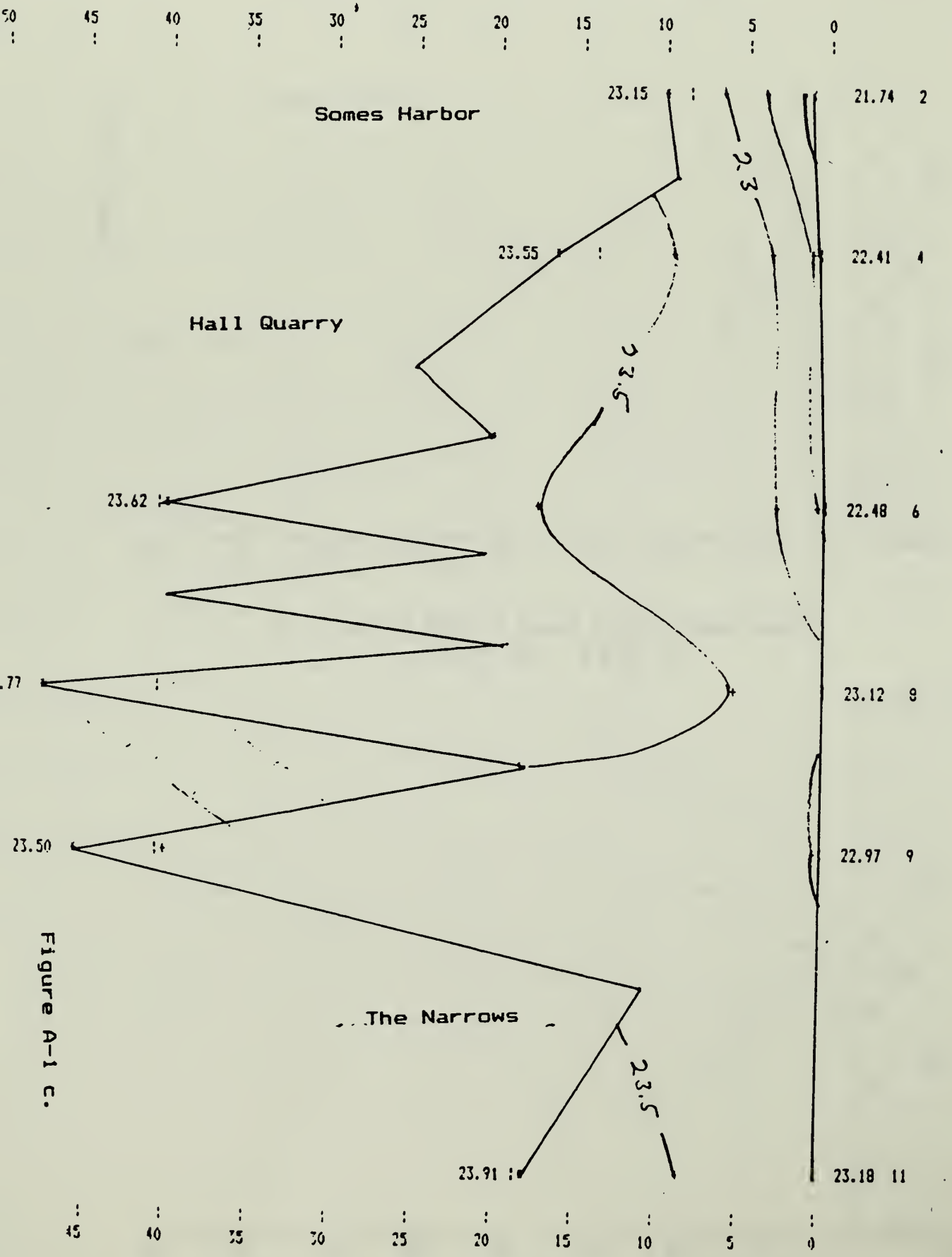


Figure A-1 c.

Somes Sound Cruise 5 August 13, 1986 Station # 9
44 18.6 N 68 18.8 W

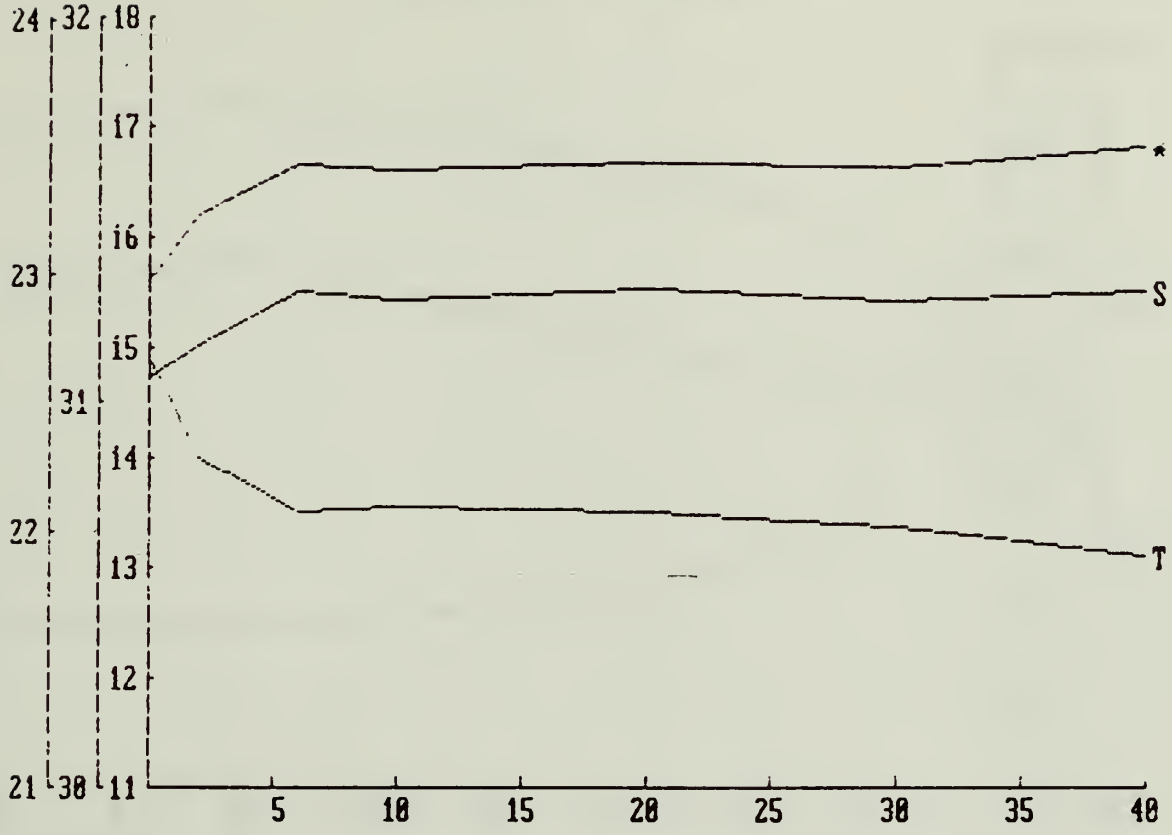
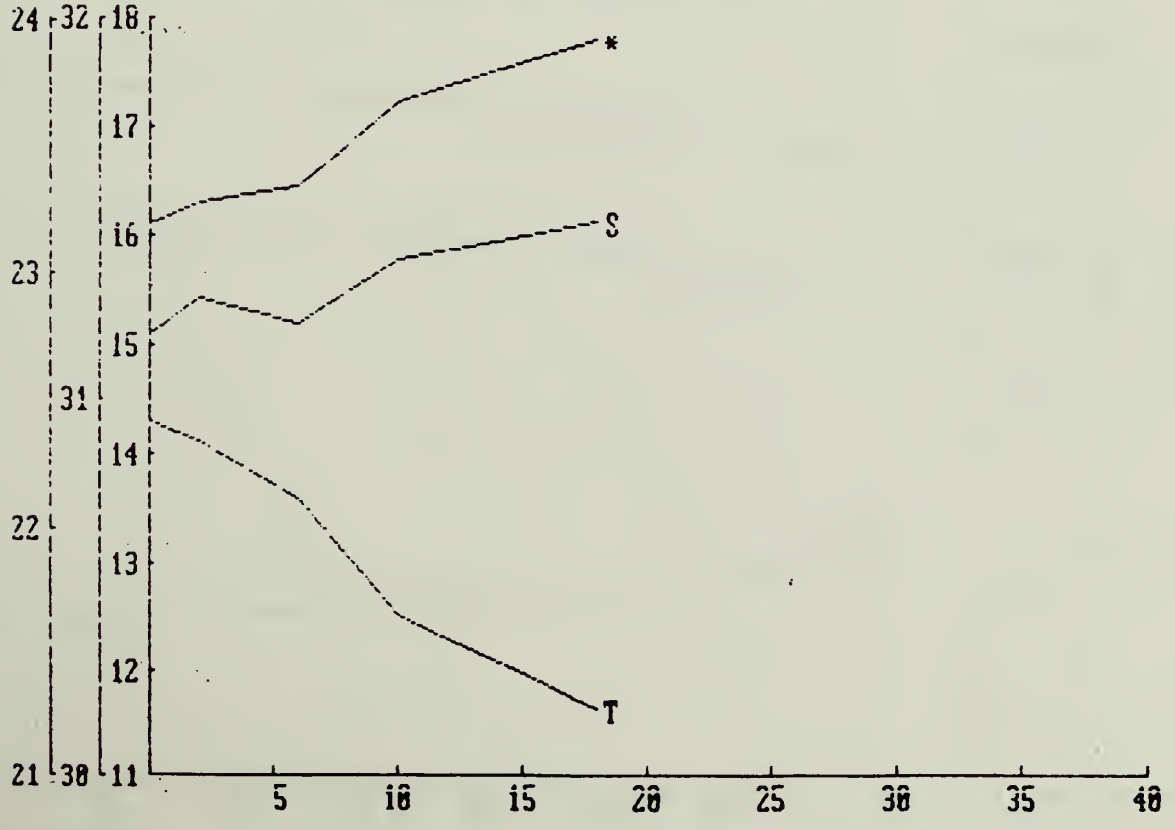


Figure A-2 c.

Somes Sound Cruise 5 August 13, 1986 Station # 11
44 17.3 N 68 18.5 W



Somes Sound Cruise 5 August 13, 1986 Station # 6
44 20.8 N 68 18.9 W

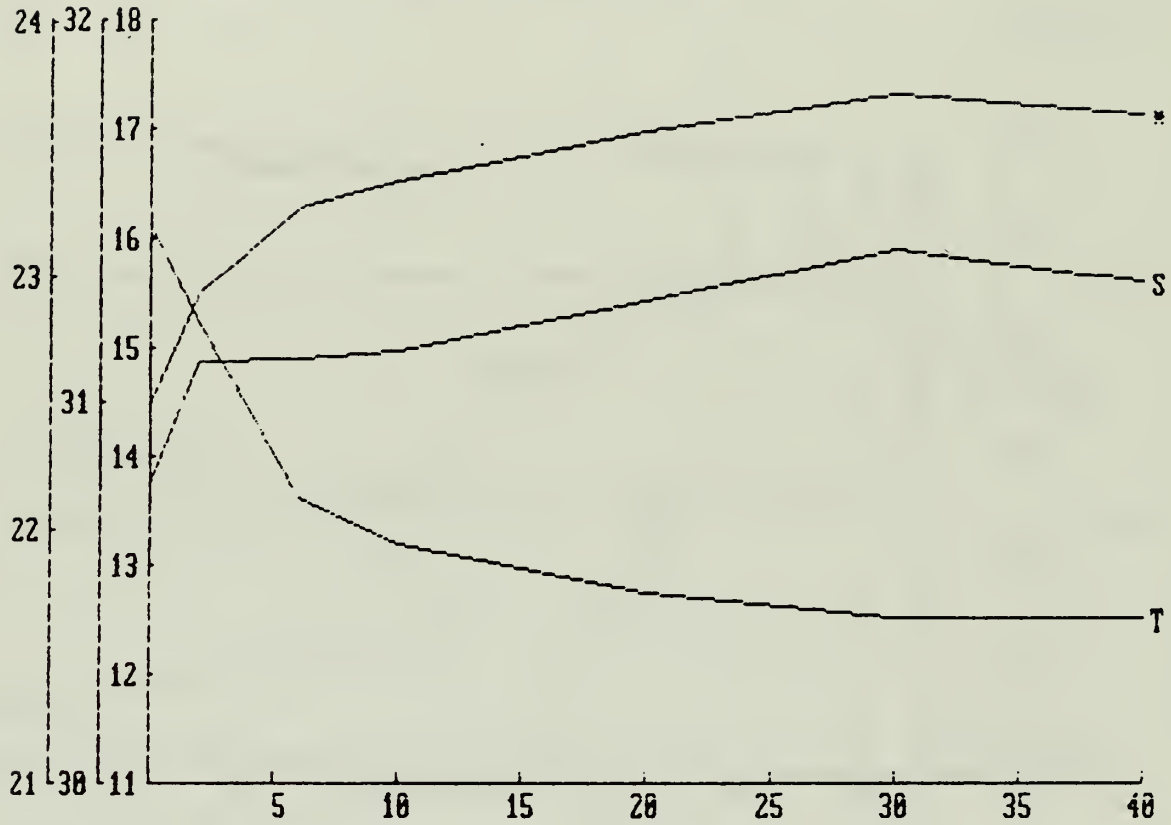


Figure A-2 b.

Somes Sound Cruise 5 August 13, 1986 Station # 8
44 19.3 N 68 18.8 W